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SOME NEWLY DISCOVERED COAL-SEAMS NEAR THE YAW RIVER, PAKOKKU DISTRICT, UPPER BURMA. BY G. DE P. COTTER, B.A. (DUB.), F.G.S., *Assistant Superintendent, Geological Survey of India.* (With Plates 5-12.)

Introduction.

IN the first quarter of 1913, I geologically mapped part of the Pakokku district in the Pauk sub-division, which is traversed by the Yaw River, and affords an excellent section through the Tertiary rocks of Burma. A topographical map on a scale of 1 inch =1 mile is published by the Survey of India and is numbered Sheet 84, K-7.

I have already alluded to this area in a paper entitled "Notes on the value of Nummulites as Zone Fossils" (*Rec. Geol. Sur. Ind.*, Vol. XLIV, p. 52).

In the sandstones overlying the nummulitic shales which in the above quoted paper I termed the Yaw stage, I found numerous coal-seams. The examination of these was postponed till the following field season, but I collected one specimen from a seam exposed close to Tazu village. It gave the following proximate analysis:—

Moisture	16·88
Volatile matter	38·10
Fixed carbon	35·72
Ash	9·30
	100·00

In Februray 1914, I showed these coal-seams to Dr. H. H. Hayden, Director, Geological Survey of India, and received instructions to open up the seams and to measure and sample them. Mr. Sethu Rama Rau, Sub-Assistant, Geological Survey, was deputed to assist me in the work, which was commenced on the 16th of March and completed in a month. The present paper sets forth the results of our examination.

In all twenty-two average samples were obtained. Each sample was taken by cutting out the coal in a regular groove from the top to the bottom of the seam, by handpicking and rejecting all clay partings, and by subsequent coning and halving. Five sketch maps of the more important exposures were made; the sketch map of the Yekyin Chaung (plate 11, fig. 3) has been prepared by the plane-table and steel tape, while the remaining maps were made by pacing and pocket-compass. Mr. Sethu Rama Rau is responsible for the sketch maps of the Thongwa and the Newe Chaungs.

Geology and structure.

The geology and structure of the area can be seen from an examination of the map and sections accompanying this paper (plates 9 and 10). The formations mapped are :—

I. Recent Alluvium.
II. Irrawaddy Sandstones.
III. Pegu Series.
IV. Yaw Shales.
V. Pondaung Sandstones.
VI. Tabyin Clays.

When examining the Yaw River section, I was unable to map with certainty the same boundaries as those previously mapped in the Minbu district (see my paper entitled "The Pegu-Eocene Succession in the Minbu district near Ngape, *Rec. Geol. Sur. Ind.*, Vol. XLI, p. 221). This was owing to the fact that the intervening country had not been mapped. From an examination of the foraminifera and mollusca of the Yaw Shales, I regarded them as the same in age as the *Velates schmiedeli* zone of Minbu, which I described in the above quoted paper. This conjecture was subsequently corroborated by my colleague Mr. H. S. Bion, who last field-season mapped the intervening country between the Minbu section and the Yaw River section, and who found that the *Velates* zone comes stratigraphically on the top of the Yaw stage, so that the top of the Yaw Shales corresponds to the *Velates* zone of Minbu.

The Pegu Series therefore, as mapped in this area, actually do correspond in their upper and lower limits with the Pegus as

mapped in the Ngape section in Minbu. They include the upper Pegus, which in Minbu are highly fossiliferous sands and thin shales; the clays and shales, which contain *Lepidocyclina theobaldi* and other foraminifera, and which I conjectured might correspond to the Sitsayan Shales of Lower Burma, and the sandstones underlying them, containing the fossil-beds which I marked D, E, and F. But although the Pegu series can be separated into these three sub-divisions in the Ngape section, such sub-division becomes impossible in the Yaw section, since the upper Pegus have become fluviatile, the *Lepidocyclina theobaldi* clays have disappeared and are represented by sands, similar to those above and below, while the underlying sandstones contain only fresh or brackish water fossils such as *Cyrena*. Sub-division is therefore impossible on the lines adopted in Minbu.

My colleagues Mr. G. H. Tipper, Mr. H. S. Bion and myself have decided to use the terms Pegus (restricted), Padaung Clays, and Shwezetaw Sandstones to indicate each of the three sub-divisions of the Pegus mentioned above. The name Padaung is taken from a village situated upon the *L. theobaldi* clays and marked on the map accompanying my paper on the Ngape section. The name Shwezetaw is taken from a famous pagoda of that name at the village of Payaywa which will also be found marked on the same map.

The coal-bearing sandstones of the Yaw River section correspond to the lowest of these three sub divisions, *viz.*, the Shwezetaw Sandstones, which contain the fossil beds marked D, E, and F on my map.

The Yaw stage corresponds to the *Velates schmiedeli* zone and some of the beds below it, while the Pondaung sandstones correspond to the massive sandstones which form the Nwamataung Hill-Range, and which in Minbu contain the bed H. The Tabyin Clays are largely concealed by soil and alluvium in Minbu. The Yaw Shales, Pondaung Sandstones and Tabyin Clays are all Eocene in age.

The whole series from the base of the Irrawaddy Sands to the base of the Eocene, I believe to be conformable. There is certainly no discordance of dip at any part of the series. It is likely, however, that there has been an interruption of sedimentation at many horizons causing what may be termed local unconformities. The Irrawaddy basin during tertiary times was a geosynclinal area, and we may suppose that the geosyncline continued to subside slowly

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The whole series from the base of the Irrawaddy Sands to the base of the Eocene, I believe to be conformable. There is certainly no discordance of dip at any part of the series. It is likely, however, that there has been an interruption of sedimentation at many horizons causing what may be termed local unconformities. The Irrawaddy basin during tertiary times was a geosynclinal area, and we may suppose that the geosyncline continued to subside slowly

throughout the Tertiary period. When the rate of deposition was faster than the rate of subsidence, we find very shallow water deposits, with much local unconformity, using the word in the sense of interruption of sedimentation; these local unconformities doubtless indicate the emergence of land in the Tertiary sea. But this emergence of land must not be taken as indicating an upheaval, but as merely a retardation of subsidence, so that the sediments have had time to fill up the sea locally. We must recognise also that the Pegu and Irrawaddy Series are regressive series, and that the change from marine deposits in the Pegus of the south of Burma to the entirely fluviatile or very shallow water deposits of the Pegus of the Yaw River section in Pakokku indicates a gradual retreat of the Tertiary sea to the south. Each bed may be regarded as imperceptibly regressive from the immediately underlying one.

This state of affairs gives rise to a regular lateral variation in each bed. Thus the Padaung Clays are deep water clays with limestone in the Ngape section. At Ngahlaingdwin in the north of Minbu, there is no intercalated limestone, but the clays are still well developed. Finally the clays grade into sands about the latitude of the Saw-Seikpyu road in the south of Pakokku as my colleague Mr. H. S. Bion has shown. In the Yaw section nothing but current-bedded sandstones are found at this horizon.

I have frequently observed also that many beds when traced northwards, after passing through the current-bedded sand phase, finally end up as red earth beds or ferruginous conglomerates, and become indistinguishable from those of the Irrawaddy series, so that it becomes a matter of extreme difficulty to draw geological boundaries near the flanks of the geosyncline.

The hypothesis that the Pegus and the Irrawaddies are both regressive series is well supported by the results of field work in Minbu and Pakokku. It would be incompatible with this hypothesis to suppose that the Irrawaddies could in these districts be transgressive or could overlap the Pegus. Possibly cases of supposed overlap may be really explained as erroneous mapping of different red earth beds as being one and the same horizon.

Geological boundaries.

The geological boundaries mapped in this area are not always well defined in the field, and a few descriptive remarks are necessary. The boundary of the Irrawaddies and the Pegus is a red earth bed, continuous over the whole of the sheet, over 100 ft., thick in most exposures,

often containing white pebbles, and on the whole an easily mapped horizon. From Mr. Bion's work, I believe it to be approximately the same horizon as that mapped in the Ngape section of Minbu. The upper and lower boundaries of the Padaung Clays are obliterated, but just above this horizon, there is a well defined stratum of ferruginous conglomerate which is developed in the north of the sheet. The boundary of the Pegus and the Yaw stage is somewhat ill defined in the south of the sheet. The Pegus as a whole are sandstones, while the Yaws are shales and clays with marine fossils. But on the Pegu-Yaw boundary there are alternates of shale and sand. It is purely a matter of convention as to whether these should be mapped with the Yaws or with the Pegus.

The boundary of the Yaws and the Pondaung sandstones is well defined, and the change from shale to sandstone at this horizon is sharp. The top of the Pondaungs is marked by oil-bearing sandstone. The boundary of the Pondaung sandstone and the Tabyin Clay is certainly the worst and most unreliable boundary in the whole of this area, since the change from the sandstones to the clays is a gradual one. Owing to the heavy soil-cap and dense jungle, one cannot do strike-mapping; it is therefore very easy to map different horizons as one and the same, when traverse-mapping this boundary. In most sections the Tabyin Clays are sheared and rolled by the movement of the massive Pondaung sandstones over them, and show considerable contortion. Dips in these clays are wholly unreliable.

Rolling of strata is also seen in the Yaw Shales exposed in the Yaw River section, but is developed in a much less degree. In the coal-bearing strata in the lower Pegus, rolling is also seen, but is usually slight.

Structure.

The structure can be seen from an examination of the sections on Plate 9. There is a rapidly rising anticline with a syncline to the west. North of the Yaw, this anticline forms the Pondaung range of hills. The anticlinal and synclinal crests become faulted north of the Yaw River, and there is a tendency towards isoclinal structure about two miles north of the river.

The coal-seams may be divided into three areas:—

(1) The seams running from the Yaw River half a mile S. E. of Letpanhla village in a S. W. direction to the crest

of the Pondaung fold. (See Plates 10, 11). The dip varies between 40 degrees at the Yaw River to close on 30 degrees near the crest of the fold.

(2) The seams running from the crest of the Pondaung fold in the Yekyin Chaung, north westwards past Tazu village along the western flank of the anticline. All this coal dips steeply and is usually inclined at angles over 60 degrees. I have not sampled this steeply dipping coal at all. It is much sheared and compressed. A photograph of these seams opposite Tazu village is shown on plate 6.

(3) The seams exposed in the gently dipping western flank of the syncline west of Tazu village. The dip varies from about 10 degrees in the north to about 20 degrees in the south. It has been examined in the Shanthe chaung north of the Yaw River, and in the Kan. Thongwa and Newe Chaungs south of the Yaw River. (See plates 11, 12).

Besides these, I have marked upon the geological map (plate 10) a coal-seam in the Pondaung Sandstones. The occurrence does not appear to be of economic importance, and need not be mentioned again.

I shall describe in detail the seams of the first and third of these areas. For the sake of brevity I shall term the first area the Letpanhla Field, and the third the Tazu Field.

I. The Letpanhla Field.

The seams extend from a point on the Yaw River half a mile S. E. of Letpanhla village to the crest of the Pondaung fold to the south-west. The outcrop is about 1½ miles in length, without reckoning its probable extension some distance north of the Yaw River. But north of the river the seams have not been examined.

A sketch-map on a scale of 16 inches = 1 mile is shown on plate 11, fig. 3. There are a group of thick seams above and numerous minor seams below. The thick upper seams have been excavated at four points marked on the map. Three of these localities are in the

Yekyin chaung and one in the Yaw River. I commence by a description of the most southerly.

Excavation No. 1.—The section is as follows:—

		Ft.	In.
Top of cliff, surface soil and purple shale unestimated.			
Ochreous and carbonaceous shale with three 3″ coal-seams		2	0
Carbonaceous shale with one 1″ seam		1	10
Coal and carbonaceous shale mixed		0	11
Sandy clay		4	7
Coal and Clay mixed		1	4
Ochreous sands		6	9
Coal	Sample No. 1	1	5
Pink Sandstone	Sample No. 1	0	2½
Coal	Sample No. 1	0	8½
Blue clay		3	3
Coal		0	3
Sand		0	3
Coal		0	4½
Carbonaceous shale with one 1″ band of coal		1	2
Coal	Sample No. 2	1	3
Carbonaceous clay	Sample No. 2	0	3
Coal	Sample No. 2	0	6½
Carbonaceous clay		0	2½
Light grey clay		1	0
Coal and clay mixed half and half		0	7
Coal, Sample No. 3		1	2
Carbonaceous clay with thin coal-seams		1	0
Clay and shale with one 1″ band of coal		3	3
Coal with ½″ bed of sand 1″ from bottom		0	7½
Carbonaceous shale with occasional pockets of coal		1	4½
Coal		0	4
Clay		0	1
Coal	Sample No. 4	2	0
Clay		1	0
Coal		0	9
Carbonaceous shale with ochre		3	0
Coal, Sample No. 5		3	6
Carbonaceous shale		0	5
Coal		0	4
Carbonaceous shale, bottom unseen but upwards of		1	0

In this section, of a thickness of over 28 ft. of strata nearly 13 ft. are coal. The two best seams are those from which samples 4 and 5 are taken, these two seams together make a thickness of

6 ft. 7 in. of available coal. The numerous partings between the seams are of course a great defect, and would greatly increase the cost of mining. The observed dip was at 29 degrees to 141 degrees east of north. The angles of dip are however not wholly reliable owing to a very slight roll of the strata, and I believe that some angle between 30 and 33 degrees would be more generally correct for this part.

Excavation No. 2.—In this section there are two seams—an upper poorer seam and a lower thick seam, overlain by purple shale with massive sandstone above. The section is as follows:—

		Ft.	In.
Coal, Sample No. 6		1	5
Carbonaceous shale		0	5
Grey sandy clay, about, grading into		3	6
Ochreous clay grading to carbonaceous clay, about		3	6
Coal	Sample No. 7	0	3
Carbonaceous shale		0	3
Coal		2	7
Carbonaceous shale		0	2
Coal		1	1½
Carbonaceous shale		0	1½
Coal		2	4½

Here the partings are thin and of little consequence and the seam may be regarded as Coal 6 ft. 4 in.

Both these seams contain thin plates of gypsum developed along the joint planes. For this reason the coal is apt to split up into small pieces, while it is more compact in Excavation No. 1. There are also in some specimens occasional minute specks of iron pyrites. There is a certain amount of moisture in the joint planes, and no doubt the high percentage of water must be discounted somewhat to allow for percolation of surface water into the seams.

Below this seam in this section the following strata are exposed:—

	Ft.	In.
Blue clay, about	12	0
Carbonaceous clay with strings of coal	2	0
Clay and unseen beds, about	18	0
Carbonaceous clay, bottom unseen but upwards of	3	0

Excavation No. 3—

	Ft.	In.
Massive sandstones with shale bands in the lower 200 feet.		
Poor coal, Sample No. 8	1	6½
Clay, about	6	0
Coal ⎫	1	5
Clay ⎪	0	1
Coal ⎪	0	2
Clay ⎪	0	0½
Coal ⎪	0	11
Clay ⎬ Sample No. 9	0	1
Coal ⎪	1	6
Clay ⎪	0	0½
Coal ⎪	1	1
Clay ⎪	0	0½
Coal ⎭	0	8½

Below this, the seam is poor and is as follows :—

	Ft.	In.
Clay	0	1½
Coal	0	2
Clay	0	3
Coal	0	3

This lower part of the seam was not included in the sample. Below this, the section is continued as follows :—

	Ft.	In.
Clays, about	15	0
Carbonaceous shale with strings of coal . .	2	0
Clay	6	0
Impure coal with clay and ochre, half and half .	1	9
Light grey clay	1	0
Carbonaceous clay	2	0
Light grey clay, bottom unseen, upwards of . .	1	0
Unseen beds, about 30 or 35 ft.		
Massive sandstones, with coal-measures containing the lower poorer seams underlying.		

Excavation No. 4 on south bank of Yaw River.—There is a small dip fault in this section, as will be seen from the map. The throw is about 8 ft. Disregarding the fault, the section is :—

	Ft.	In.
Massive fossil wood sandstones.		
Coal	0	10
Carbonaceous shale	0	9
Clay	5	6
Coal	1	9
Clay	0	2½
Coal Sample No. 11	1	11
Clay	0	1
Coal	0	5½
Impure coal with shale	0	6

Here the main seam is reduced from its former thickness of over 6 ft. to a thickness of 4 ft. 1½ inches of good coal, with 6 inches of impure coal beneath.

Below this seam the section is continued as follows :—

	Ft.	In.
Shales and sandstones, about	13	0
Massive sandstone, about 40 or 45 ft. (see last entry of excavation No. 3).		
Blue Clay, about	3	0
Carbonaceous shales	1	2
Coal with one 1 inch band of clay	1	3
Carbonaceous shale	1	1
Coal	0	8
Shale, carbonaceous in lower part.	4	6
Coal and clay mixed	0	5
Carbonaceous clay	1	1
Impure coal	0	3½
Coal, Sample No. 12	1	3½
Blue clay, about	6	0
Impure coal	0	6
Shale	0	2
Coal	0	4
Unseen beds, about	25	0
Blue shale, about	18	0
Coal	1	4
Shale and then sandstone underlie this.		

Other exposures in the Yekyin Chaung.—Some account of the beds above and below the main seams is necessary, in order to indicate the nature of the roof and the floor above and below

the seams, and also to form an estimate of the minor seams below the main seams above described. In the map on plate 11 the various localities in the Yekyin Chaung are indicated by Roman numerals. At I the crest of the Pondaung fold crosses the Yekyin Chaung. Massive sandstones are exposed, containing pockets of coal. The dip of these sandstones west of the crest is at 80 degrees to 200 degrees east of north. The base of these sandstones is seen at II, where there is a waterfall and a deep pool in the chaung. The dip here is at 34 degrees to 120 degrees east of north. The sandstones are here underlain by a bed of carbonaceous shale 3 ft. thick. Below this at III is a bed of purple ochreous shale from 80 to 100 ft. thick. Underlying this comes about 100 ft. of massive fossil wood bearing sandstones. At IV the main seams are very badly exposed, but are seen underlying these sandstones. Further down the chaung, we see the same horizon at Excavation No. 1, which has been already described. The beds underlying the main seams exposed near V are:—

	Ft.	In.
Sand and clay about	11	0
Ochreous and carbonaceous clay with strings of coal .	2	4
Shale, clay and sandstone, ill seen, about	20	0

And at VI, below the above:—

	Ft.	In
Hard blue clay	2	0
Blue clay and coal, half and half	2	8
Light blue clay	0	9
Impure coal	1	8
Clunchy blue clay, about	4	0
Heliotrope coloured sand and clay, well bedded below, clunchy above, shown on map, about	18	0
Clunchy clay grading into thin bedded carbonaceous clay with ochre, about	9	0
Coal	1	3
Coal and carbonaceous ochreous shale	0	9
Bluish sandy clay, about	25	0

And below this at VII, comes:—

	Ft.	In
Coal	0	1
Carbonaceous clay	0	3
Coal	0	8
Carbonaceous clay	0	1
Coal	0	10

These last five entries further down the stream are represented by :—

	Ft.	In.
Coal, of which top 4″ is lightly impure . . .	1	2
Carbonaceous shale	0	4
Coal	0	9
Purple shale, about	11	0
Sandstones with many clay partings, about . . .	20	0

And below this at VIII, are seen :—

	Ft.	In.
Carbonaceous shale	0	6
Coal	0	9
Carbonaceous shale	0	7
Coal	0	11

Continuing the section downwards, we have :—

Ochreous shale	13	0
Clay with sandstone lenticles	11	0
Impure coal	0	6
Ochreous shale and clay, about	3	0

And at IX—

Coal	2	1
Unseen beds, roughly about	30	0

And at X, another seam as follows :—

Coal	0	5
Carbonaceous clay	0	9½
Coal	0	6½
Carbonaceous clay	0	10½
Coal	0	8
Carbonaceous shale and clay, bottom unseen.		

These are the lowest beds exposed in the Yekyin Chaung. I have not seen any good coal seams in the beds underlying this lowest seam. The exposures are poor.

Proceeding down stream along the bed of the Chaung, we now recross upwards over the beds above described.

At XI the seam previously seen at X is exposed. At XII the previous entry Coal—2 ft. 1 in. is represented by

Coal, Sample, No. 10	1	10

The dip here is at 33 degrees to 136 degrees E. of N. At XV is a mudstone with *Cyrena* shells, which forms a reef in the middle

of the stream bed, this reef dips at 50 degrees to 110 degrees east of north; the steep angle of dip being due to local rolling.

Although I have noted all the thicknesses of the various seams in this portion of the Chaung, they do not appear to present any features of interest, and I have omitted them as unnecessary.

Of the seams below those of the main excavations it is now evident that with one exception all are less than 2 ft. thick and that they are usually disintegrated by partings of clay and carbonaceous shale.

Dips.

At XVI there is another abnormal dip of 47 degrees to 140 degrees east of north.

At XIV the dip is to 140 degrees E. of N.

At XX the dip is at 28 degrees to 114 degrees E. of N. This dip is more reliable than the dips at XV and XVI since it is taken from a thick bed of sandstone, while the others are from thin beds in shale, which are very apt to be crumpled and thus deceptive. We have seen that the dip at the Main Excavation No. 1 was at 29 degrees to 111 degrees E. of N. At II, the angle was 34 degrees. I think therefore that the true dip of the main seams must be some figure between 29 and 34 degrees. The dip of the lower seams is more apt to vary owing to rolling than that of the main seams, since the latter are in part protected by the massive sandstone capping them.

The dip in the Yaw River at XXIV is at 39 degrees to 95 degrees E. of N.

We may regard the general dip of the coal-seams in the Letpanhla field as about 30 degrees in the south, and as gradually increasing to about 40 degrees near the Yaw River.

Amount of coal available.

The main seam is over six feet thick for a distance of about half a mile in outcrop, and diminishes between Excavations No. 3 and No. 4 from about 6 ft. to 4 or $4\frac{1}{2}$ ft. For purposes of rough estimation of the quantity of coal available we may suppose that there is an outcrop of a 6 ft. seam half a mile in length and an outcrop of a 5 ft. seam one mile in length.

II. The Tazu Field.

The gently dipping seams running from north to south, west of the village of Tazu, were excavated in four stream sections in

the Shanthe, Kan, Thongwa and Newe Chaungs. I commence by a description of the sections in the most northerly or the Shanthe Chaung.

Excavation in the Shanthe Chaung.—The position of the seams is shown on plate 11, fig. 2.

There are three fairly good seams exposed here, and above these some poor worthless seams. At section No. I the lowest of the three seams is exposed and measures as follows :—

		Ft.	In.
Grey clay		5	0
Slightly impure coal .	Sample No. 15 . . .	1	3
Carbonaceous clay .		0	6
Coal		0	5
Clay		0	3
Coal		2	6

Here the dip is at 12 degrees to 95 degrees E. of N.

NOTE.—In this and all other samples, the clay partings are not included in the sample.

At section II the upper of the three seams is exposed, it is :—

	Ft.	In.
Coal, containing two 1″ clay partings ; Sample 17 .	4	0

The dip here is at 14 degrees to 80 degrees E. of N.

The middle of the three seams is exposed at section III, it is :—

	Ft.	In.
Coal, with one 1″ clay parting ; Sample 16 . . .	3	6

This is underlain with grey clay and overlain with clay and ochre. The dip is at 12 degrees to 95 degrees E. of N.

Section IV shows a worthless seam, situated above the three good seams above described. It is :—

	Ft.	In.
Coal	1	6
Purple ochreous shale	3	0
Carbonaceous clay with strings of coal	2	0
Coal	0	8
Clay	1	8
Coal	0	6
Clay, over 1 ft., bottom unseen.		

Section V also shows a worthless upper seam, possibly the same as that of section IV.

The measurement is :—

	Ft.	In.
Coal	0	2
Clay	0	4
Coal	1	0
Ochreous clay	3	7
Mixed coal and clay	2	4
Clay	2	5
Coal	0	6
Clay, bottom unseen.		

The dip is here at 13 degrees to 85 degrees E. of N.

There are a few other very thin seams in the stream sections, but they are not worth describing. The differences in dip observations are to be accounted for by (1) experimental error, (2) surface warping of strata, and (3) possibly actual rolling.

Excavation in the Kan Chaung, ¾ mile S. S. W. of Tazu.—The position of the seams is shown on plate 11, fig. 1.

In this section the strata are rolled, so that a small fold is produced. This fold cannot however be called an anticline as it is confined to the soft coal-measures and is merely due to a roll in these soft beds produced by horizontal movement of the sandstones above over the beds below. The normal dip is to E. N. E. at angles varying from 10 to 15 degrees. Three abnormal dips shown on the map, *viz.*, at 30° to 220° E. of N. at section 3; at 45° to 290° E. of N. a few yards further to the S. W., and at 30° to 250° at section 4 illustrate the roll of the strata.

The seams are very badly exposed. At section No. 1 the measurements were :—

	Ft.	In.
Ochreous coal	1	1
Clay	0	3
Coal	0	9½
Carbonaceous clay, over 2 ft., bottom unseen.		

At section No. 2 the following :—

Surface soil	3	0
Ochreous clay	2	0
Coal	0	6
Carbonaceous shale	1	0
Coal	1	0
Carbonaceous shale	0	6½
Coal, Sample No. 14	3	0

At section 3 the measurements are :—

		Ft.	In.
Carbonaceous and Ochreous shale	. . . . .	2	$8\frac{1}{2}$
Coal	Sample No. 13 (from the three coal seams, omitting clay partings).	0	6
Clay		0	2
Coal		0	$10\frac{1}{2}$
Clay		0	11
Coal		1	$10\frac{1}{2}$
Gray clay, over 2 ft., bottom unseen.			

I have mentioned above the abnormal dips in this section, which show the roll of the strata. Normal dips are :—

At waterfall — at 15° to 70° E. of N.

N. E. of Section 3 — at 10° to 70° E. of N.

At section 1 — at 15° to 75° E. of N.

Excavations in the Thongwa Chaung.—This section is shown on Plate 12, fig. 2.

As will be seen from the map, the main coal seams are three in number, and are overlain by alternations of sandstone and shale. The measurements of the three main seams are :—

		Ft.	In.
Upper seam—			
Impure coal with gypsum and ochre . .		0	6
Grey clay		0	4
Coal		0	6
Clay		0	6
Coal, Sample No. 21		2	6
Between the upper and middle seams are seen—			
Clay and shale, about		12	0
The middle main seam measures-			
Coal with one $\frac{1}{4}''$ parting . . .	Sample No. 20	1	7
Impure coal and carbonaceous shale .		0	7
Coal with one 1″ lenticle of clay . .		2	1
The seam is poorer below, and shows—			
Grey clay		0	10
Coal with clay partings . . .		0	$4\frac{1}{2}$
Coal		0	7
Between the middle and the lower seam are—			
Shales, about		24	0

The lower seam measures as follows:—

	Ft.	In.
Coal, with one ½″ parting 4″ from top and two 1″ partings at 8″ and 1′ 3″ from top, and one 3½″ parting at 2′ 6″	3	10
Clay	0	5
Impure coal	1	0
Clay	1	2
Impure coal	0	5
Coal	0	7
Shale	0	2
Coal	0	4
Shale	0	2
Coal	0	3
Carbonaceous shale with coal veins	0	9
Impure coal	0	10
Carbonaceous shale with thin veins of coal	1	0
Coal	0	6
Carbonaceous shale	0	9
Coal, bottom unseen. Here the water-level was reached in the pit. It is probable that this last item is thin.		

From the 3 ft. 10 in. seam noted above Sample No. 22 was taken.

Below these main seams other seams are exposed in the stream bed, none are of any importance: the thickest seam being not more than 1½ ft. in thickness.

The dip at the exposures of the main seams is at 17° to 80° E. of N.

Excavations in the Newe Chaung.—A sketch map of this stream is given on Plate 12, fig. 1.

This chaung runs more or less along the strike of the rocks, and there is a thick covering of alluvium; the sections are therefore not nearly so good as those of the Thongwa Chaung.

The main seams are exposed at excavations 1, 2, and 3.

At excavation 1, the sequence is slightly confused by a small fault, but I obtained the following measurements :—

		Ft.	In.
Sandstone		2	0
Coal	Sample No. 18	2	$3\frac{1}{2}$
Grey clay		3	0
Coal	Sample No. 19	1	2
Clay		0	$1\frac{1}{2}$
Coal		0	2
Clay		0	$1\frac{1}{2}$
Coal		0	5
Carbonaceous shale		0	9
Coal		2	4
Carbonaceous clay		0	2
Coal		2	3
Carbonaceous clay		0	5
Coal		0	7

A few feet below this seam a third seam is exposed, which is however quite useless, the thickest bed of coal being 8″. We may therefore speak of two main seams in this area, *viz.*, the upper, from which sample 18 was taken, and the lower, from which sample 19 was taken.

At excavation 2, the upper seam measures :—

	Ft.	In.
Coal	0	$2\frac{1}{2}$
Shale	0	3
Coal	0	3
Shale	0	3
Coal	0	6
Ochreous clay	0	8
Coal	2	5

Here the lower seam is not exposed.

At excavation No. 3 the upper, and part of the lower seam is exposed. The measurements are :—

Upper seam—	Ft.	In.
Coal, with stone concretion in seam	1	$8\frac{1}{2}$
Clay	0	8
Coal	2	7

The lower seam measures :—

	Ft.	In.
Impure coal	0	2
Clay	0	1
Coal	0	$4\frac{1}{2}$
Clay	1	5
Coal	1	$8\frac{1}{2}$
Carbonaceous shale	0	11
Coal, bottom unseen, but about	2	0

Other thinner seams, situated below these main seams, are exposed in the chaung, and have been measured; as however they do not appear to be of any economic importance, I omit their dimensions.

Near excavation No. 2, the dip is easterly at about 20°.

The coal-seams have not been traced further south than latitude 21° 15′, which is the southern boundary of sheet 84 K-7. But the seams might be prospected southwards into the adjoining sheet with advantage. The lower seam at excavation 1 measures nearly 7 ft., but is marred by the frequent partings. The upper seam shows improvement as one traces it southwards. At excavation 1 it is 2′ $3\frac{1}{2}$″ in thickness, while at excavation 3, it is 2′ 7″ thick.

Other exposures.—There is a rather bad exposure of the coal in a tributary of the Thongwa Chaung, between it and the Kan Chaung. The main seams do not appear to be exposed on the Yaw River west of Tazu. Halfway between Tazu and Kaingma on the south bank of the river, some poor seams are exposed; these I believe correspond to the lower thinner seams of the Thongwa and Newe Chaungs.

III. Analysis of Coal.

The twenty-two samples of coal for analysis were prepared and analysed under the supervision of Mr. A. K. Banerji, Assistant Curator, Geological Survey, from bulk samples obtained by me in the field from those seams which in the lists of sections given above

I have marked as having been sampled. I give on this page a table showing the results of the analysis.

Analyses of Letpanhla and Tazu Coals.

No. of sample.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	REMARKS.
1	17·67	36·89	33·60	11·84	Ash light brown.
2	17·85	35·65	35·90	10·60	Ash dark brown.
3	17·07	35·39	34·90	12·64	Ash brown.
4	17·38	35·04	37·98	9·60	Ash light brown.
5	18·64	33·46	37·92	9·98	Ash brown
6	15·63	33·37	29·32	21·68	Ash reddish brown.
7	17·30	34·02	36·02	12·66	Ash dark brown
8	19·42	32·06	33·16	15·36	Ash brown.
9	19·68	34·38	37·38	8·56	Ash reddish brown.
10	18·04	35·20	36·98	9·78	Ash brown.
11	19·22	34·38	37·04	9·36	Ash brown.
12	15·92	37·36	35·22	11·50	Ash dark brown.
13	20·76	33·48	36·20	9·56	Ash brown.
14	21·60	32·54	36·96	8·90	Ash dark brown.
15	21·19	32·51	34·04	12·26	Ash brown.
16	18·98	36·52	34·44	10·06	Ash reddish brown.
17	21·33	34·73	35·22	8·72	Ash brown.
18	20·28	31·74	39·26	8·72	Ash dark brown.
19	18·54	32·12	36·60	12·74	Ash brown.
20	18·02	35·06	39·64	7·28	Ash buff.
21	19·82	31·98	37·54	10·66	Ash light pinkish brown.
22	16·94	33·00	33·18	16·88	Ash brown.

NOTE.—None of the above samples cake.

Table showing the Sulphur contents of eight samples.

No. of Sample.	S (as SO_3)	S (as Sulphide).	Total Sulphur.
1	0·395	1·890	2·285
7	1·298	2·685	3·983
9	0·338	1·800	2·138
11	0·698	1·940	2·638
13	Not separately estimated.		2·778
16	Ditto		4·399
18	Ditto		4·782
21	1·216	4·412	5·628

Table showing the calorific power of eight samples.

No. of Sample.	Calorific Power (determined by bomb calorimeter).
1	4820
7	4517
9	4663
11	4784
13	4499
16	4519
18	4835
21	4510

In order to ascertain how far the high percentage of moisture could be reduced by simple drying, two samples were powdered and air-dried for a week. The test was not perhaps performed under very favourable conditions in the moist air of Calcutta during the rains. Sample 6 after air-drying showed 12·36% of moisture, while sample 17 showed 15·52% of moisture, as against 15·63% and 21·33%, respectively.

IV. The value of the Coal-seams.

In Vol. XXXIII of the Records of the Geological Survey of India, two papers deal with occurrences of coal in Burma, the

fields described being the Lashio coal-field, and the Namma, Mansang, and Man-se-le fields.[1]

The proximate analyses of these Shan State coals are strikingly similar to those obtained from the Pakokku seams. Both show a remarkably high percentage of moisture, and an excessive proportion of volatile matter as compared with fixed carbon. The ash content is fairly low, but in all other respects the analysis is very disappointing. The Pakokku seams appear on the whole to have a higher percentage of sulphur. The sulphur has been estimated separately according as it occurs as sulphate or as sulphide. The joints of the seams are frequently filled with thin layers of gypsum, and probably all the sulphate occurs either as gypsum or as soluble sulphate. Traces of iron pyrites are often visible.

Owing to these defects, the raw fuel may be assumed to be unsuited for most purposes, except perhaps for dressing tools in forges. The high percentage of sulphur is harmful even for this purpose. It could not compete with coal imported to Upper Burma from India, unless some expensive process of briquetting was resorted to.

The coal can be mined in fairly hard and large lumps, but these rapidly crack to fragments on exposure to air, owing to the loss of moisture.

The roof of the seams is not good, even where it is sandstone, the sandstone is fairly soft. Expensive timbering would be necessary.

The distance from the Letpanhla field to Seikpyu on the Irrawaddy River is about 46 miles over not very hilly country.

Summing up therefore the various defects of these seams, we find :—

(1) The seams are marred by frequent partings, making them expensive to work.

(2) The roof is poor, and would require expensive timbering.

(3) The quality of the coal is very poor owing to the high percentage of moisture, the small amount of fixed carbon, and the presence of excessive sulphur.

[1] The Lashio Coal-field, Northern Shan States, by T. D. LaTouche and R. R. Simpson. (*Rec., Geol. Surv. Ind.*, XXXIII, p. 117.)
The Namma, Man-sang, and Man-se-le Coal-fields, Northern Shan States, Burma, by R. R. Simpson. (*Ibid*, p. 125.)

(4) It is not near any railway and is 46 miles distant from the river.

Against this, it is to be remembered that Bengal coal usually fetches well over Rs. 20 per ton in Upper Burma and the Oil-fields. I may say unhesitatingly that this coal would be useless if situated in a similar position in India, but the high price of Indian coal in Upper Burma makes me unwilling to condemn these fields, although I doubt very much that they are likely to prove of economic value for many years to come.

EXPLANATION OF PLATES.

PLATE 5.—Photograph showing Excavation No. 1 in the Yekyin Chaung.

PLATE 6.—Photograph of the steeply dipping seams opposite Tazu village.

PLATE 7.—The excavations of the three main seams in the Thongwa Chaung.

PLATE 8.—Excavation No. 1 of the main seams in the Newe Chaung.

PLATE 9.—Geological sections across geological map.

PLATE 10.—Geological map of part of Pakokku district, from sheet 84 $\frac{K}{7}$.

PLATE 11.—FIG. 1.—Sketch-map of the Kan Chaung, showing coal-seams.
FIG. 2.—Sketch-map of the Shanthe Chaung, showing coal-seams.
FIG. 3.—A plane table sketch-map of the coal-seams in the Yekyin Chaung and the Yaw River.

PLATE 12.—FIG. 1.—Sketch map of the Newe and Yegyo Chaungs, showing seams.
FIG. 2.—Sketch-map of the Thongwa Chaung, showing seams.

THE MONAZITE SANDS OF TRAVANCORE. BY G. H. TIPPER, M.A., F.G.S., *Officiating Superintendent, Geological Survey of India.* (With Plates 13 to 17.)

INTRODUCTORY.

THE monazite-bearing character of the sands was discovered by Mr. C. W. Schomburg acting on behalf of the London Cosmopolitan Mining Syndicate in the year 1909. In 1909-10 I had an opportunity of examining them and the observations then made are embodied in this paper. I had no opportunity for extended geological work. My results would have been very meagre but for the very interesting specimens which friends in Travancore sent me. I would particularly thank Mr. H. P. Herbert, the then Manager of the Morgan Plumbago Co., and Messrs. E. Masillamani and I. C. Chacko, State Geologists.

Geology of the State.

The only easily accessible papers dealing with the geology of Travancore are by W. King[1] and R. B. Foote.[2] Recently the reports of the State geologists have been published in Trivandrum.

In its broad outlines the geology is very simple, the greater part of the state being constituted of gneissose rocks (charnockites and leptynites). These gneissose rocks form the high hilly and plateau country and also the lower terraced plain, falling gradually to sea-level. In addition to the dyke rocks associated with the charnockites, there are important pegmatite intrusions of much later date which cut the older rocks and may possibly be of the same age as the pegmatites of the Nellore district and other parts of India.

Resting on these Archæan rocks in the immediate neighbourhood of the coast are patches of Upper Tertiary strata (the Warkalli beds) which correspond to the Cuddalore sandstones. At the type

[1] W. King, General Sketch of the Geology of the Travancore State, and the Warkalli beds and reported associated deposits at Quilon in Travancore. *Rec., Geol. Surv. Ind.*, XV, 87 and 93, 1882.

[2] R. B. Foote, The Geology of South Travancore. *Rec., Geol. Surv. Ind.*, XVI, 20, 1883.

locality these beds closely resemble those forming at the present day. Of still later date are the older consolidated blown sands, generally bright red in colour: the estuarine and marine beds described by R. B. Foote from near Cape Comorin.

The coloured and variegated sands[1] of the coast were commented on by both King and Foote.

Distribution of the Monazite.

Monazite is widely distributed over the state. Shows of the mineral can be obtained by washing the sands of many of the rivers and streams and it is present in small quantities in the soil in many localities. Widely distributed though it is, there are only a few places where concentration has given rise to deposits of sufficient richness to be called monazite sands. These places are all in the vicinity of the sea-coast. No concentrates seem to occur in any of the rivers.

Distribution of the Monazite Sands.

From a point on the south-east coast where the state marches with the district of Tinnevelly to Quilon on the west coast five deposits were seen. They may be briefly designated:—

Cape Comorin—Liparum
Muttum Pudur
Kovilam
Anjengo—Warkalli
Nindikarai (Quilon).

Between these productive spots there are long stretches of barren sand with only faint traces of monazite.

General Character of the Sands.

Although each deposit has certain peculiarities, all present a great many features in common. In colour they are usually black due to the presence in predominating quantities of magnetite and ilmenite. They are sometimes red when garnets are in excess. Where there is abundance of quartz or calcite, a grey sand is produced. Excess of monazite gives a yellowish tinge. The other

[1] It may be of interest to note that samples of these sands were collected by W. King and R. B. Foote in 1882, the monazite being identified as zircon.

commonly occurring mineral in the sands is zircon, but practically all the constituent minerals of the Archæan rocks can be found in one or other of the deposits. The zircons often show crystal outlines, while the other minerals are usually rounded. The monazite in particular is always well rounded, and after an examination of many sands I have never seen a specimen which showed any approach to crystal outline. If the relative hardnesses of the commonly associated minerals are compared, it will be seen that monazite is softer than almost all of them. With the exception of quartz and calcite, the densities of the minerals vary from 3 to 5·5.

Physical Character of the Monazite.

In the sands the monazite occurs as small rounded grains (Plate 13, fig. 1) varying from 0·1 to 0·2 millimetres in diameter. Certain deposits are characterised by the constant presence of larger, or smaller, or irregularly shaped, grains. Its colour is best described as resembling amber. Its density is 5·191. Its refractive index is very high. It invariably shows an absorption spectrum in which the didymium lines are well marked. This fact was made use of in the field and in the laboratory for the identification of grains and thin sections. For the field a Browning direct vision spectroscope was used. It is quite easy to separate a few grains on the page of a pocket-book and, in bright sunlight, to get a spectrum at once. For laboratory work a Swift direct vision instrument was first used in connection with a Dick petrological microscope. One of the great advantages of this apparatus is that it is provided with a slit moveable in two directions so that even a small grain will fill the aperture. The spectroscope does not give sufficient dispersion for fine work. More recently a Hilger spectroscope has been used, fitted with a comparison scale. This instrument leaves nothing to be desired.

Other Accumulations containing Monazite.

Sand Dunes.—Considering that these dunes represent material blown from the shore, it is merely a question of the relative sizes of grains of different minerals, assuming that they are all the same shape, as to whether the wind is strong enough to drive them along If the grains are considered to be approximately spherical, the relative volumes of quartz and monazite which can be moved by

the same wind are as 2 : 1. In nature things are not so simple, but it seems probable that a ground wind such as often blows along the coast at Cape Comorin moves rounded grains more readily than flakes or angular fragments. With a high wind such as will raise a sand storm conditions are reversed and angular fragments tend to be more easily raised and blown. At any rate both processes have the same effect, the gradual accumulation of material some distance away from the sea shore. The grinding action of the waves on the minerals of the sands eventually reduces them to such a size that they can be moved along by the wind. The action of the wind is not possible until the sun has dried the top layers of sand. Wet sand seems to be unacted on. Sand dunes are well seen at Cape Comorin, between Muttum and Colachel, at Anjengo and many other localities along the coast. The amount of material in these dunes is considerable, with a very fair percentage of monazite in places near concentrated sands. The difference in size between the lighter minerals such as quartz and calcite and the heavier such as monazite, ilmenite and magnetite could easily be made use of as a means of obtaining a monazite concentrate. It is hardly necessary to point out that the monazite in the dunes is not lost but may by a reversal of conditions be returned to the beach.

The older Dunes.—At Cape Comorin and at Muttum there are older dunes at a higher level than those forming at the present day. They are bright red in colour, due partly to the decomposition of the iron-bearing minerals they contain and partly to the red lateritic dust blown and washed on to them. These dunes are more solid than those of the present day, but have obviously been formed in the same manner. The proportion of monazite they carry seems to be greater. At Cape Comorin they are rapidly coming under cultivation and it is possible to obtain a good concentrate from the irrigation channels bordering each field. At Muttum they are too high above the surrounding country to be of much use. They bear a few palmyra palms. At both places they are being rapidly denuded and the monazite is returning to the sea beach.

On the low cliffs south of the Residency at Cape Comorin there is a very interesting rock. It is a blown sand cemented by calcite to a hard compact material. In some of its upper layers it contains land shells of the genus *Helix*. The main mass of the rock is of the minerals of the beach, generally rounded and including monazite, ilmenite, magnetite, garnet and quartz. In addition there are many

calcareous fragments of organic origin including worn foraminifera. (Plate 13, fig. 2.)

Older Concentrates.—At the base of the Warkalli cliff, at the time of my visit, there was exposed a dark brown ferruginous grit which on closer examination was seen to be composed very largely of the minerals of the present beach, ilmenite, magnetite, garnet and monazite, the latter in some quantity. It was obvious that here was exposed an old beach concentrate and its degradation by wave action was undoubtedly adding to the monazite content of the shore. The Warkalli cliff gives the following generalised section. At the top is a thick band of lateritoid material, succeeded by dark coloured clays with lignite logs and iron pyrites. At the base is the old sea beach The clay beds are so similar to those forming at the present day in the backwaters that it is impossible to resist the conclusion that this was really their origin. The beds at Warkalli then give evidence of a change from beach conditions to terrestrial and finally of elevation of the deposits so formed to their present position. A similar section is seen near Villenjen. It is possible that similar older concentrates occur at the base of the late Tertiary beds in other places.

I have described these older deposits at some length because I see in them proof that the present-day conditions of concentration on the sea beach are merely a continuation of older conditions. In other words I believe that the monazite has been on the same places for some considerable period of time.

The Rivers in relation to the Monazite deposits.

With one exception, the deposits described are not associated with any large stream and at the present time it is difficult to see how the heavy minerals washed out of the rocks and soil can reach the sea in any quantity, since the rivers empty themselves into inland lagoons and backwaters. These large bodies of water are, in the winter season at least, completely cut off from the sea by bars. The bar may possibly be broken down during the flood season. Even then it seems almost impossible for the current of a river to be strong enough to carry the heavy mineral particles through a lagoon or backwater to the sea. The check on the current at the moment of entry to a larger body of comparatively still water must be so great that the major portion of the burden is dropped. I repeat

that under present circumstances I am unable to believe there is any addition to the heavier minerals of the beach.

If a map of Travancore is examined, it will be seen that the backwaters on the west coast are elongated in a direction parallel to the coast and that their mouths are some distance southward. Where no backwater has been formed, the stream itself has been deflected for some distance towards the south. These facts indicate a strong set of currents running from north to south along the coast and causing a piling up of accumulations in that direction. On the east coast of India the set of the currents is from south to north with a transference of material in that direction.

With the exception of the Anjengo-Warkalli deposit, all the other monazite sands are accumulated to the north of and in amongst the few rocky promontories there are on the west coast. The Cape Comorin mass is caught up in the bays and rocks of the east coast where the set of the current changes. This position of accumulation at first appears anomalous, but it is apparent on consideration that there is the position of greater scour. This is shown by the fact that the profile of the beach is invariably steeper in these places than in the long stretches of unproductive sands which separate them. If this greater scour is conceded, then it follows that a part of the lighter minerals is not deposited but carried on. The effect of this scour must sooner or later cease as the coast becomes more and more uniform in outline The Nindikarai deposit is being gradually cut off from the concentrating action by the accumulation of a shallow shelving beach of ordinary sand.

The Anjengo Warkalli deposit is exceptional because it owes its monazite to the denudation of older concentrates in the immediate neighbourhood. It differs from any of the other monazite sands in having a very much higher proportion of the ordinary lighter minerals. It is an ordinary beach sand with an exceptional amount of monazite.

The North-east and South-west Monsoons.

The quiescent period of the north-east monsoon is the time when I believe the actual concentration proceeds at its greatest rate. The action of the currents along the coast is not interrupted by violent winds. The sorting action of the waves is seen at its best. It is during this period that the greater slope of the beach comes into play. The under-tow of the waves gradually pulls the

lighter materials down this slope leaving a concentrate of heavier minerals. The continuation of the process will sort the material still further until only the most dense are left. Near Cape Comorin at low tide the beach is often a glistening mass of rounded grains of yellow monazite. The continual wear and tear of the grains against one another produces the rounded forms so characteristic of these sands. It is possible that the concentrate is continued for some distance below low water level. On the shallower slopes where the unproductive sands are, the selective action of the waves is practically *nil*. The inclined plane is of such low angle that the undersuck is of no effect.

I had no opportunity of seeing the Travancore coast during the south-west monsoon. The following notes deal with probabilities and not with observed facts. At this season the direction of the wind is at right angles to that of the currents. The winds are also more violent than those of the north-east monsoon. The probable effect will be the heaping up of ordinary beach material over the whole coast including the concentrated sands. The concentrated sands are not solid monazite sands, but in section are seen to be composed of concentrated layers of varying thickness separated by layers of unsorted beach material. During a long continued south-west monsoon one may assume the accumulation of so much ordinary sand that the north-east monsoon conditions are unable to cope with more than the upper part. There would then be left an unsorted layer of white sand between two sorted layers of black sand. A thick layer of concentrated sand indicates a long continued period of quiescent conditions.

Origin of the Monazite.

Monazite was first discovered *in situ* by Mr. Herbert in association with the graphite of south Travancore. Later E. Masillamani found it in the younger pegmatites. I saw only one of these occurrences and the following description is based on specimens sent to me. These seem to be of sufficient interest to justify the notes.

There does not seem to be any evidence that the pegmatite intrusions follow any particular direction, but it is probable that they bear some relation to the strike of the gneissose rocks. The intrusive masses occasionally attain a considerable size and as is

common in all pegmatites the minerals tend to segregate. The quartz is sometimes dark brown or reddish in colour with parallel rows of minute inclusions. The felspar is usually decomposed, but seems to be often perthitic, or an intergrowth of two different felspars. Occasionally it forms a micrographic intergrowth with the quartz. In one case it seems to be albite, in which the twin lamellæ fade away before they reach the edge of the crystal. The biotite is of a dark bronze colour and forms conspicuous patches in the rock. The mica is rarely sufficiently well developed to be worth working. Ilmenite when present also forms segregation patches. The monazite has been the first mineral to crystallise but it rarely shows good crystal forms. It has been found in the middle of quartz (Plate 14, fig. 1) and in felspar (Plate 14, fig. 2). In the latter case it is surrounded by an aureole of decomposition and shows multiple twinning. When biotite and ilmenite are present, it seems to associate itself with these minerals (Plate 15, figs. 1 and 2).

The association with graphite is interesting. In the graphite mine at Vellanad, 16 miles north-east of Trivandrum, monazite was found in a rock filling a fault crack. This rock (Plate 16, fig. 1) is composed mainly of brownish crystals of monazite in a matrix of felspar with a little quartz. Thin veins of graphite cut the rock and are later than either of the other minerals. The monazite, yellow in thin sections, is often twinned and encloses small patches of a reddish-yellow mineral which I suggest may be thorium silicate. On its discovery this rock was supposed to be entirely secondary. It is more probably a very rich patch of monazite-bearing pegmatite.

The remaining specimens (Plate 16, fig. 2) show monazite occurring as small veins in masses of graphite. In these the monazite looks different and has a decided greenish tinge. It may be secondary. There does seem, however, to be in Travancore some connection between the pegmatite intrusions and graphite. It is possible to obtain pegmatites showing large pseudo-crystals of graphite which look in every way original. It is, however, impossible to say whether the large vein masses lately mined were due to the intrusions.

The monazite in all the slides is yellow in colour. It has one perfect cleavage parallel to *a* and the twinning plane is parallel to this cleavage. The refractive index by van der Kolk's method is about 1·81. The fluid used was methylene iodide saturated with sulphur. It is optically positive.

Possibility of Occurrence in the gneissose rocks.

After my examination of the monazite sands I came to the conclusion that the mineral must occur as an accessory in the gneissose rocks which occupy so large a part of the state. It seemed to me that in this way only could one account for a mineral so widely spread and so abundant. I have been unable to verify this supposition by an examination of such rocks as I was able to collect; I was unable to trace it either in slides or concentrates. In spite of this negative evidence I do not yet think it proved that monazite does not occur in the gneissose rocks.

Analyses.

The estimation of the thorium content of the monazite was undertaken by Dr. W. A. K. Christie. The material selected was not a sand or a concentrate but was prepared from a specimen composed of monazite, felspar, a litte quartz and graphite. It was first hand-picked and then the separation completed with a heavy liquid (Sonstadt's solution). It was thus possible to prepare monazite free from zircon or any other mineral likely to complicate the analysis.

The method employed was that of Benz (*Zeit. fur angew. Chem.*, XV, 297, 1902). The amount of thorium present as ThO_2 is 6·00 per cent. The silica percentage is 1·55. The molecular ratio ThO_2 : SiO_2 is 1 : 1·13, a result in close agreement with that of Penfield (*Amer. Jour. Sci.*, ser. 3, XXIV, 250, 1882). The thorium is present as a normal silicate.

Two analyses were published in the Bulletin of the Imperial Institute, XI, 103 5, 1911, without any author's name. The amounts of thoria present in two samples of magnetically separated sand were respectively 8·5 per cent. and 10·08 per cent.

Recently S. J. Johnstone (*Jour. Soc. Chem. Ind.*, XXXIII, No. 2, 57, 1914) gives 10·22 per cent. and 8·65 per cent. as the thoria contents of two samples of Travancore monazite, isolated from concentrates.

These results indicate a considerable variation in the amount of thoria present in Travancore monazite.

Distribution of Monazite in other parts of India.

The following notes are based on examination of a number of sands and concentrates brought to Calcutta at different times.

From what has already been written it seems natural to conclude that monazite is most likely to occur in those part of India where charnockites are well developed. The sands have, however, not been collected with sufficient care to settle the question accurately. Of the States and districts bordering on Travancore, sands from Cochin (K. K. Sen-Gupta) did not show any trace, while it occurs widely in the Tinnevelly district (R. B. Foote) in the older dunes, in the dry beds of streams draining eastward from the hills (K. C. Biswas and H. A. Pearson) and in the beach sands where they have undergone slight concentration. It has not been noticed in the sands from Ennore near Madras. It occurs in the streaks of black sand at Waltair (S. W. Kemp) and at Bimlipatam (F. Cross). Similar streaks near the entrance to the Chilka lake in Orissa also contain it (N. Annandale). Sands from the pegmatite districts of Nellore and Bihar and Orissa have so far failed to yield any trace. It occurs sparingly in concentrates from Idar, Central India (C. S. Middlemiss). No monazite was found in washed sands from the Indus river above Attock (C. M. P. Wright). Concentrates obtained during the course of tin dredging in Southern Burma have not shown it. One of these concentrates was extremely interesting as it consisted almost wholly of topaz in small crystals and cleavage flakes (J. R. Booth).[1]

Finally I should like to express my somewhat belated thanks to all those, officials and others, who made my stay in Travancore pleasant, and particularly to the Hon'ble Mr. R. C. C. Carr, then Resident at Trivandrum.

EXPLANATION OF PLATES.

PLATE 13.

FIG. 1.—Monazite grains separated magnetically from sand, Liparum, near Cape Comorin.

FIG. 2.—Blown sand cemented by calcite, Cape Comorin.

[1] In dealing with concentrates, it is often an advantage to be able to obtain a section of some of the constituents. This can be done by embedding them in moderately fluid plaster of Paris. After the plaster has set, it is kept for at least a day in fluid Canada balsam at a fairly high temperature (107°C) to allow the balsam to penetrate thoroughly. A thin section can then be made by rubbing down in the usual way. This method prevents the tearing out of grains as happens if balsam alone is used. It may be pointed out that under this treament the plaster of Paris commences to crystallise in bundles of fine needles.

PLATE 14.

FIG. 1.—Monazite in quartz, from a pegmatite near (west of) Eslandimangalam, Tovala Taluq. South Travancore.

FIG. 2. Twinned monazite in felspar. Same locality.

PLATE 15.

FIG. 1. Monazite in biotite. segregation patch in pegmatite. Ashamboo Tea Estate road, South Travancore.

FIG. 2.—Monazite pegmatite, monazite in contact with biotite and ilmenite.

PLATE 16.

FIG. 1.—Monazite felspar rock with a little graphite. Vellanad, 16 miles north-east of Trivandrum.

FIG. 2.—Monazite with graphite. Same locality.

PLATE 17.

Map showing the distribution of the monazite sands, sand dunes, older dunes and Warkalli beds in Travancore.

A LOWER CRETACEOUS FAUNA FROM THE HIMALAYAN GIEUMAL SANDSTONE TOGETHER WITH A DESCRIPTION OF A FEW FOSSILS FROM THE CHIKKIM SERIES, BY DR. ALBRECHT SPITZ (Vienna). TRANSLATED BY E. VREDENBURG, B.L., B.SC., F.G.S., *Superintendent, Geological Survey of India.* (With Plates 18 and 19 and text figures 4-11.)

THE specimens described in the following pages include the collections obtained in Spiti, partly by Stoliczka,[1] partly in more recent times, by Krafft and Hayden; they also include some of Griesbach's collections from Hundes. The specimens were sent to Vienna together with the fauna from the Spiti Shales. I am deeply indebted to the kindness of the late Professor Uhlig for entrusting me with the revision of the present fauna.

Some time previous to the publication of the work in which Stoliczka first established the main outlines of the geology of Spiti, fossils from the Gieumal sandstone had already been described by Blanford[2] and by Salter,[3] but they were united with Jurassic fossils from the Spiti Shales as though belonging to a single palæontological zone. Precise stratigraphical details were first published in 1866[4] by Stoliczka, who described from the Gieumal sandstone a few bivalves of indifferent value for determining the age of the rocks. In consequence of the middle Jurassic age then attributed to the Spiti Shales, the immediately overlying Gieumal sandstone was regarded as upper Jurassic. In later years this error was rectified. Griesbach[5] considered that the deposition of the Gieumal sandstone commenced in upper tithonian times: Oldham[6] spoke of it as "possibly" Cretaceous. As a result of Uhlig's study of the fauna of the Spiti Shales, the Cretaceous age of the Gieumal sandstone was

[1] Stoliczka published a list of the forms which he identified in *Mem., Geol. Surv., India*, Vol. V, 1866, pages 112, *et seq.*
[2] *Journal, Asiatic Society of Bengal*, 1863, p. 124.
[3] Palæontology of Niti, 1865, p. 89.
[4] l.c.
[5] *Mem., Geol. Surv., India*, Vol. XXIII, 1891, p. 80.
[6] Geology of India, 1893, p. 294.

at last definitely established by Diener,[1] and this view has now met with general acceptance.[2] The overlying Chikkim series, consisting of limestones and shales had already been referred to the Cretaceous by Stoliczka on account of the Foraminifera and Rudistæ[3] which it contains.

A.—THE GIEUMAL SANDSTONE.

The specimens communicated to me indicate that in Spiti as well as in Hundes[4] the Gieumal standstone contains three lithological types connected by intermediate gradations, each of which contains a characteristic assemblage of fossils :—

(1) A coarse, porous, calcareous sandstone of an ochreous colour due to its ferruginous contents, with conspicuous grains of white quartz ; fossils are plentiful and relatively well preserved.

(2) A darker-coloured, grey rock, siliceo-calcareous, and always somewhat ferruginous which one might describe as a fine-grained grauwacke-slate ; it contains flakes of muscovite. This variety as well as

(3) a light-grey, non-ferruginous quartzite or quartz-slate, poor in lime, is crowded with badly preserved fossils, mostly casts and impressions.

Since the second type of rock has yielded fossils indicating different chronological horizons, it appears evident that these three divisions are connected with facies and not with stages.

The fossils from each of these divisions will be considered separately.

I. SOFT SANDSTONE.

CARDIUM GIEUMALENSE, n.f., Pl. 18, fig. 5, a, b, c.

A large form with remarkably small, rounded, symmetrically situated umbo, anteriorly to which there is a shallow furrow which becomes more pronounced as the shell grows larger and which extends obliquely (in the direction of the radial striations) downwards. The ornamentation consists of numerous, crowded radial ribs, in the intervals between which finer ribs are regularly intercalated These

[1] *Denkschrift Wiener Akad. d. Wissensch,* 1895, pp. 55, 56.
[2] See Hayden, *Mem., Geol. Surv., India,* Vol. XXXVI, 1904, p. 86.
[3] (l.c.,p. 116.)
[4] See Griesbach, *Mem., Geol. Surv., India,* Vol. XXIII, p. 80.

are crossed by concentric striations of varying degrees of fineness. The shell is strongly convex. Large specimens sometimes exhibit irregularities in the convexity towards the inferior margin together with some waviness of the ribs. The hinge exhibits the normal characters of the genus.

This beautiful species is distinguished from all other Cretaceous species of *Cardium* by its feebly prominent, centrally situated umbo, by its regularly alternating sculpture, and the absence of nodosities. The nearest ally is *Cardium Lundgreni* Vogel from the upper *mucronata*-chalk of Holland distinguished by a larger umbo, different ornamentation and greater breadth. *Cardium Cottaldinum* d'Orb. from the Lower Greensand, as figured by Woods,[1] has the same shape as the Indian fossils, but the ribs are all of equal width.

Cardium Gieumalense is the commonest fossil from the soft sandstone. It also occurs in the quartzite, Lingti river. Stoliczka and Krafft-Hayden collections.

CARDIUM cf. GIEUMALENSE, n.f. Pl. 18, fig. 4.

This form is closely related to the above, from which it is distinguished by its more pointed, less symmetrically situated umbo, and especially by its much feebler convexity.

The related *Cardium semipustulosum* Mull.[2] from the lower Senonian entirely differs in its ornamentation, as is also the case with *Cardium pullatum* Stol.[3] from the "Trichinopoly group."

Numerous specimens. Gieumal. Krafft-Hayden collection.

CARDIUM n. sp. Ind. Pl. 18, fig. 3.

This form is represented only by a single left valve with subcentral, depressed umbo, slightly deflected anteriorly. The outline is orbicular. The rather weathered ornamentation consists of alternately broader and narrower straight ribs. Only one lateral tooth of the hinge is visible. This is also a very distinct form; related species, such as *Cardium scrobiculatum* Stol.[4] from the Trichinopoly group, differ by their more prominent umbo and their ornamentation.

Only one specimen. Gieumal. Krafft-Hayden collection.

[1] Cret. Lamellibr. of England, *Pal. Soc.*, 1908, pl. XXXII, fig. 11.

[2] Holzapfel, Mollusken d. Aachener Kreide, *Palæontogr.* Vol. XXXV, pl. XVIII, figs. 11, 12.

[3] Cretaceous of Southern India, *Palæont. Ind.*, Vol. III, pl. 11, figs. 8-10.

[4] Cretaceous of Southern India, *Palæont. Ind.*, Vol. III, pl. 11, fig. 14.

OSTREA sp.

1866. Ostrea sp. Stoliczka. *Memoirs, Geol. Surv., India,* Vol. V, p. 114.

This shell unfortunately exhibits only its internal characters; the central portion of the specimen is smooth, while coarse folds are developed round its margin. So far as any determination is at all possible, it would seem to be related to the group of *Ostrea* "*Minos* Coquand[1] or to that of *Ostrea Barrandei* Coquand.[2]

Only one specimen. Gieumal. Stoliczka collection.

GRYPHÆA aff. BAYLEI GUER. Pl. 18, figs. 20*a*, *b*, 21.

Choffat-Loriol, Et. Strat. et pal. d'Angola, *Mém. Soc. de phys. et de science. nat. de Genève*, Vol. 30. No. 2, pl. V, figs. 19-21, p. 93.

Two lower valves recall the abovementioned form by their completely rounded spherical umbo and the absence of a lateral lobe, but they differ owing to their narrower shape. They exhibit coarse concentric swellings.

Gryphæa Baylei appears to occur at Angola in the upper Cretaceous. Coquand has illustrated a flat shell which greatly resembles the upper valve of the Indian form, though without any radial striations, and which may be specifically identical.[3]

Gieumal, Krafft-Hayden collection.

All the other remains of Ostreidæ are unfortunately undeterminable (including the one mentioned by Stoliczka[4] as *Gryphæa* sp.).

PECTEN sp. Pl. 18, fig. 22.

The shape closely recalls *Pecten Agassizi* Pictet and Loriol[5]; the ornamentation, however, is different, the Indian fossil exhibits rather widespread, fine radial ribs alternating with still finer ones; traces of ribbing are discernible with the aid of a lens. This kind of ornamentation, which so frequently occurs amongst the Gieumal fossils differentiates the present form from the numerous other Cretaceous

[1] Monographie, pl. 73, figs. 5-9, Neocomian.
[2] op. cit. pl. 12, figs. 1-4 Campanian.
[3] Monographie du Genre Ostrea, 1869, pl. XLVI, figs. 5-9, Cenomanian.
[4] *Mem., Geol. Surv., India*, Vol. V. 1866, p. 114.
[5] Neocomian des Voirons, pl. IX, figs. 2-4 in Mat. pour la Pal. Suisse, III eme serie.

Pectinidæ. The casts of *Pecten Agassizi* also exhibit ribs which are not observed in the case of the Indian fossils.

Gieumal. Krafft-Hayden collection.

TELLINA sp. Pl. 18, fig. 19.

Tellina Beushauseni, Muller,[1] is closely related. The Indian form is somewhat more strongly convex anteriorly; the radial ribs are only just indicated posteriorly and are fewer; the angulation enclosing the area has a much steeper downward slope. The anterior margin unfortunately is not preserved. The German fossil occurs in the lower senonian.

Two specimens. Gieumal. Krafft-Hayden collection.

Opis sp., further described with the fauna of the quartzite where it chiefly occurs, has also been found in the soft sandstone.

2. ARGILLACEOUS QUARTZITIC SLATE.

PSEUDOMONOTIS SUPERSTES n.f. Pl. 18, figs. 6, 7.

1863 Avicula echinata? Blanford, *Journal Asiat. Soc. of Bengal*, 32, page 137.

1866 Avicula echinata Stoliczka, *Mem. Geol. Surv., India*, Vol. V, page 114.

The two valves of this species differ greatly from one another. The right valve is relatively somewhat larger and less convex than the left one. The umbo scarcely projects beyond the straight hinge line. There is a large posterior wing-shaped expansion, scarcely distinct from the posterior margin and a diminutive anterior ear with a deep byssal notch. The anterior margin is rounded. The ornamentation consists exclusively of concentric striations, except for some radial striæ on the wing-like expansion, increasing in distinctness towards the hinge line. The left valve is smaller, more convex, with a much more prominent umbo, with a feebly independent posterior ear, while anteriorly there is no indication of any such feature. The anterior margin is strongly convex. The ornamentation consists of fine radial ribs locally exhibiting a regular alternation of thicker and thinner elements. They carry minute granules caused by the occurrence of concentric striations. It is

[1] *Abhandlungen d.k. preuss, geol. Landesanst*, New Series, part 25, atlas, pl. IX, fig. 8.

particularly worth mentioning that the ornamentation shows no tendency to become effaced towards the anterior and posterior margin. In both valves, the substance of the shell is thin.

This species has a remarkably Jurassic facies, so much so that Stoliczka unhesitatingly referred it to *Avicula echinata* Sow. This group appears generally to have become extinct in Cretaceous times, though it just survived in America. *Meleagrinella* (=*Eumicrotis*=*Pseudomonotis*) *abrupta* Whitfield [1] from the Cretaceous "lower green marls" of New Jersey, recalls many specimens of the right valve; nevertheless the anterior margin extends more prominently anteriorly, while the left valve lacks all traces of radial ornaments. *Avicula pectinata* Sow. in Woods [2] is referred by Woods to the genus *Oxytoma*, indeed the details of the byssal notch of the anterior ear are not in accordance with *Pseudomonotis*. Amongst Jurassic forms, *Pseudomonotis echinata* Sow. and *Pseud. Braamburiensis* Morris and Lycett [3] both differ by their more unsymmetrical shape, and stronger radial sculpture. A closer analogy is exhibited by certain forms from the Malm such as *Avicula Douvillei* Loriol [4], which both in shape and ornamentation closely recalls the Indian species: nevertheless, in the left valve the posterior expansion is more rounded, while in the right valve the anterior margin slopes more steeply from the umbo. Moreover radial ornaments appear to be wanting in the right valve of the Indian fossil. *Pseudomonotis tenuicostata* Grepp.[5] is extraordinarily similar, only slightly more oblique.

This fossil appears to have already been noticed by Blanford (see the synonymy); Stoliczka has also referred to Blanford's previous notice.

This is the commonest fossil in the quartzitic slate. It also occurs in the quartzite. Gieumal; Lingti-river.

Stoliczka and Krafft-Hayden collections.

ARCA (?) sp. , Pl. 18, fig. 17, a, b. c.

This is a small obliquely quadrangular form, with a small anterior and a large posterior wing. The hinge is straight, the umbo rounded. The ornamentation consists of narrow, prominent ribs, often of alter-

[1] Raritan clay and Greensand marls, *Mem., Un. St. Geol. Surv.*, IX, pl. XIV, figs. 11-14.

[2] Cret. Lamellibr. *Pal. Soc.*, 1905, pl. VIII, figs. 8-14.

[3] Mon. Brit. Great Ool. Fossils, pl. XV, figs. 6-7

[4] Form. Jurass. de Boulogne-Surmer, II, pl. XX, figs. 3-6, p. 319.

[5] Loriol, Oxfordien du Jura Lédonien, *Schweizer pal. Abhandlungen*, vol. XXVII, pl. VI, fig. 44.

nating size. The left valve, which alone is preserved, is strongly convex.

Arca Salbieri Coquand[1] is closely related. Nevertheless the present species is more oblique, with a straight hinge; the posterior ear is more distinctly set off, and the umbo less prominent.

Grammatadon securis Leymerie[2] from the Speeton clay, is broader; the more strongly convex umbo also appears to be bordered posteriorly by an angular edge; the specimen illustrated in fig. 15 which agrees better with Leymerie's original is much broader.[3]

Numerous left valves. Chikkim, Gieumal. Krafft-Hayden collection.

CUCULLÆA (?) sp. 1 et 2.

There are two large specimens representing different species, but both unfortunately so badly preserved that they cannot be identified. One of the specimens perhaps corresponds with *Cucullæa Uhligi* described below (p. 219, pl. 19, figs. 7—9).

Chikkim, Krafft-Hayden collection.

UNICARDIUM cf. TUMIDUM BRIART CORNET, Pl. 18, fig. 16.

Unicardium tumidum Briart Cornet, Geinitz, Elbtalgebirge, 1. Unterer Quader, *Palæont.*, Vol. XX, pl. XL, fig. 4 Unterer Pläner.

In the Indian specimens the umbo is situated rather more forward; nevertheless there is a close agreement with regard to the number and shape of the prominent ribs, which are about half the width of the intervening spaces, and the occasional appearance of secondary ribs; the Indian specimens further agree in the gradual widening of the ribs with increasing growth.

Chikkim, Gieumal. Krafft-Hayden collection.

TAPES ROCHEBRUNI ZITTEL. Pl. 18, fig. 15.

Tapes Rochebruni Zittel, Gosaubivalven, *Denkschr. d. k. Ak. d. Wiss. Wien.*, Vol. XXIV, pl. 111, fig. 4.

[1] Aptien de l'Espagne. 1865, pl. XIV, figs. 7, 8, p. 137.
[2] Woods, Cretac. Lamellibr., *Pal. Soc.*, V, 53, pl. VII, fig. 14.
[3] *Mém., Soc. Géol., de France* Vol. V, pl. VII, figs. 6-7.

This small species represented by numerous specimens agrees with the Alpine fossil; the only possible difference consists in the perhaps somewhat coarser concentric furrowing of the European form.

Chikkim, Gieumal. Krafft-Hayden collection.

TELLINA cf. STRIGATA GOLDFUSS, Pl. 18, fig. 18.

Tellina strigata Goldfuss, Pl. 147, fig. 18. see also Holzapfel, Kreide von Aachen, *Palaeont.* Vol. XXXV, pl. XI, figs. 6–10.

The Indian fossil closely resembles the forms above quoted, though perhaps slightly more slender; the fine radial striations of the Aachen form are not preserved; the latter is from the lower senonian.

A single specimen. Gieumal. Krafft-Hayden collection.

APORRHAIS AFF. DUPINIANA ORB. Pl. 18, fig. 12.

Aporrhais Dupiniana Orb. in Pictet-Campiche, Mat. Pour la Pal. Suisse, 3 eme serie, pl. 92, figs. 1–3.

Numerous casts represent a form closely corresponding with the French fossil, both with regard to the shape of the shell and the presence of a nodose ornamentation, and of two keels on the body-whorl. The wing seems to differ somewhat, reaching higher in the Indian form, and it seems to possess a second deeper lobe which is broken off in the figured specimen. The French fossil is from Valange and Hauterive.

Common, Chikkim, Lingti river. Krafft-Hayden collection.

HOLCOSTEPHANUS (ASTIERIA), (of the group of Atherstoni Sharpe).

The fossil here referred to is a large fragment unfortunately only in the condition of an impression. On the umbilical side it exhibits elongated tubercles which are fairly prominent, especially on the last whorl. From each node there issues a bundle of six or seven sharp, undivided ribs, which after a very slight backward bend follow a straight course forward. The external region is not preserved. The umbilicus must have been rather narrow. So far as can be judged by the only character preserved, namely the ribbing, this form seems

very closely related to the South-African *Holcostephanus Atherstoni* Sharpe[1]. The discussion of this form by Kitchin [2] may be seen.

The form from the valanginian of Mexico described by Burkhardt as *Astieria* cf. *Atherstoni* is also very similar.[2]

Other related forms such as *Holcostephanus Astierianus* in Pictet-Campiche [3] and *Holc. multiplicatus* [4] Roemer differ either on account of the smaller number of ribs, or their dichotomous disposition.

All these forms characterise the lower neocomian and do not reach beyond the hauterivian. Only one form of the group of *Holcostephanus Astieri* constitutes an exception to this rule, having been recorded by Uhlig from the Wernsdorf beds of barremian age.[5]

In the Spiti shales there is a great contrast between the excessive abundance of the sub-genus *Spiticeras* and the scanty development of *Astieria* which is only represented by *Astieria Schenki* Opp.[6] and one species of the group of *Astieria Atherstoni*.

One specimen ? N. of Tootigaag ? (label illegible). Krafft-Hayden collection.

HOPLITES (PARAHOPLITES) sp. Pl. 18, fig. 1*a*, *b*.

A small form with very narrow umbilicus and tall aperture; the siphonal region is slightly flattened. The feebly developed crowded ribs on issuing from the umbilicus first proceed forward, then backward, and finally resume a forward course with which they extend over the siphonal region where they become rather indistinct. In the inner part of the whorl they divide into two or three branches, the most conspicuous of which seems to be the posterior one. On nearing both the umbilicus and the siphonal region they show a slight tendency to form swellings.

A very closely related form is *Parahoplites Nolani* Seunes[7] which differs by the greater width of the umbilicus. Moreover Jacob also describes a *Parahoplites* cf. *Nolani*,[8] which exactly agrees with the

[1] *Transact. Geol. Soc.*, London, 2nd series, Vol. VII, pl. XXIII, fig. 15.
The Invertebrate fauna of the Uitenhage Series, *Ann. S. Afr. Mus.* 1908, p. 187.

[2] Fauna jurassique de Mazapil, *Boll. Inst. Geol. de Mexico*, 23, 1906, Pl. XL, fig. 23.

[3] Mat. pour. la. Pal. Suisse, 2 eme, serie, pl. XLIII.

[4] Norddeutsche Kreide, Vol. XIII; see also Neumayer Uhlig, Hilsammoniten, *Palæont.* Vol. XXVII, pl. XXXIII.

[5] Cephalopodenfauna d. Wernsdorfer Sch. *Denkschr. d. k. Ak. d. Wissensch. Wien*, Vol. XLVI, 1883, p. 116.

[6] See Uhlig, *Pal. Ind., Ser.*, XV, Vol. IV, pl. VIII, fig. 2.

[7] *Bull Soc. Géol. de France*, 1887, (III) Vol. V, p. 564, pl. XIII, fig. 4, *a*, *b*, see also Jacob, *Bull. Soc. Géol. de France*, 1905 (IV). Vol. V, p. 408.

[8] Op. cit. p. 409, pl. XIII, fig. 1.

type except for its somewhat greater compression, narrower umbilicus and more quadrangular section. This form therefore approaches the Indian fossil very closely. Unfortunately it is not possible definitely to unite the two forms by a comparison with the illustrations, especially as the specimens studied by Jacob are badly preserved. This form is from Clansayes at the junction of the aptian and Gault.

Another related form is *Hoplites jodariensis* Douvillé.[1] The ornamentation, however is more prominent, and the branching of the ribs takes place, higher up along the flanks. This is a hauterivian form.

Other analogous forms of *Holcodiscus*, such as *Holcodiscus menglonensis* Sayn-Lory, differ by their more rounded siphonal[2] margin, while the ribs lack the tendency to develop nodes at the junction of the flanks with the siphonal region, upon which, moreover, they do not tend to disappear.

One specimen. Lingti river. Krafft-Hayden collection.

HOPLITES (STOLICZKAIA) cf. DISPAR ORB. Pl. 18, fig. 2.

This form is represented by a fragment of a whorl with a very characteristic ornamentation consisting of broad, slightly sigmoidal flexuous ribs which become much broader towards the siphonal region over which they apparently extend without any interruption. Intercalated between them are secondary ribs, originating at about half the height of the whorls, and likewise apparently extending over the siphonal region.

This fossil agrees so perfectly with certain stages of growth of *Stoliczkaia dispar* Orb.[3] that only in consequence of its poor state of preservation do I refrain from positive identification.

D'Orbigny's typical *Ammonites* '*dispar*[4] includes the variety with straight ribs in the adult stage, corresponding with Stoliczka's illustration.[5]

Nevertheless according to Pictet's description, there is every gradation between this variety and the forms with flexuous ribs.[6] The

[1] Esquisses geol. des Préalp. subbétiques, Thèses prés. à la fac. des. sciences de Paris, 1906, pl. XIII, figs. 7, 7*a*, p. 207.

[2] Sur la constitution du syst. crétacé aux environs de Châtillon en Diois, p. 23, fig. 6.

[3] Pictet-Campiche, Ste Croix, Mat. pour la. Pal. Suisse, 11 ème série, pl. XXXVIII, fig. 4.

[4] *Pal. française*, pl. XLV, figs. 1, 2.

[5] *Palæont. Ind.*, Cretaceous of Southern India, Vol. I, pl. XLV.

[6] Ste. Croix, II ème série, pp. 265 ff.

variety with flexuous ribs has also usually been figured under the name *dispar*, a specimen in the collection[1] of the Palæontological Institute of the University of Vienna indicates also the presence of this variety in the "Ootatoor group."

One specimen. Lingti river. Krafft-Hayden collection.

3. QUARTZITE.

AVICULA ? aff. SANCTÆ CRUCIS PICTET-CAMPICHE. Pl. 18, fig. 8.

Avicula ? Sanctæ Crucis Pictet-Campiche, Mat. pour la Pal. Suisse, V. eme ser., pl. 152, fig. 5.

The available specimens are, unfortunately, badly preserved in the umbonal region ; nevertheless, in their shape, their feeble convexity, in the slightly confused, feeble radial ribbing, with its tendency to disappear laterally, they thoroughly agree with the French form (Valange).

Common. Gieumal. Krafft-Hayden collection.

LIMA aff. ARZIERENSIS Loriol. Pl. 18, figs. 13*a*, *b*, 14.

Lima Arzierensis Loriol. Valangien d'Arzier, Mat. pour la Pal. Suisse, IV eme serie, pl. III, figs. 9, 10.

This fossil agrees thoroughly with the French form with respect to the coarse, granulated radial ribs, the gradual weakening of the ornamentation towards the sides and the pronounced convexity of the shell. At the same time the Indian fossil is more symmetrical, with alternating radial ornamentation, and a smooth wing.

Common. Gieumal. Krafft-Hayden collection.

OPIS sp., pl. 19, figs. 1*a*, *b*, *c*, *d*, 2.

1866, Opis sp. Stoliczka, North-Western Himalaya, *Mem. Geol. Surv., Ind.*, Vol. V, p. 116.

There are abundant remains of a large *Opis*, which unfortunately are all in the condition of internal casts, so that an exact identification is not possible.

[1] See Bayle et Zeiller, Explication de le carte géol. de France, pl. XLVI, fig. 2, from the "lower chalk" Choffat and Loriol, Mat. pour l'étude stratigr. et. pal. d'Angola, *Mém. de la Soc. de Phys. et d'hist. nat de Genève*, Vol. XXX, No. 2, 1888, pl. II, figs. 5-9, Gault or vraconnian.

The casts indicate a form with tall though somewhat thick umbo, slightly deflected forward, and curved inward. On the posterior margin of the umbo, an angulation extends from the apex towards the posterior margin, enclosing an area on its inner side. In front of the angulation, there is a more or less pronounced shallow depression; the anterior region only shows a keel bordered on either side by broad shallow depressions. Under the umbones is a small prominence directed inwards in which their outline is again repeated.

The lower margin is rounded, the anterior margin greatly produced, while the posterior margin slopes away from the umbo rather straight and steep.

So far as it is possible to compare casts, the nearest relative to this fossil is *Opis bicornis* Geinitz[1] from the Lower Planer (cenomanian), the correspondence between the two forms is very thorough, though the Indian fossil differs by its thicker and shorter umbo, the presence of a projection beneath the umbo, and the steep declivity of the posterior margin towards the lower margin, while in the European form the posterior margin projects considerably.

Common. Gieumal. Also one specimen from the coarse sandstone of Chikkim.

Stoliczka collection.

LIMA SP.

1866 Lima sp. Stoliczka, *Memoirs, Geol. Surv., India*, Vol. V, p. 115.

A large concentrically furrowed *Lima*, not otherwise determinable.

Gieumal. Stoliczka collection.

CARDIUM SP.

A fragment of a tall, slender *Cardium* with well-marked radial ribs.

Gieumal. Stoliczka collection.

CARDIUM n. sp. indet. Pl. 18, fig. 11*a*, *b*.

The right valve is very slender and tall, with rounded umbo feebly bent forward. The posterior margin is not sinuated, and extends

[1] Elbtalgebirge, *Palæontographica*, Vol. XX, 1st part, pl. 2, figs. 1-3.

with regular curvature from the umbo, while the anterior margin exhibits a short rounded wing. The ornamentation consists of very fine, crowded striations, for the most part arranged alternately; they combine with the lines of growth to give rise to small granules; this ornamentation extends regularly over the entire surface of the valve (unfortunately, while developing the specimen, the middle portion of the shell got lost).

This form belongs to the group of *Cardium productum* Sow.[1] Both this species as well as *Cardium Reussi* Zittel[2] are more symmetrical, with a sinuated posterior margin, and a somewhat more extended anterior ear; moreover they lack the alternating character of the ornamentation. The same differences distinguish *Cardium cenomanense* Orb.[3]

Only one specimen Gieumal. Stoliczka collection.

PANOPÆA cf. ARCUATA ORB. Pl. 18, fig. 10.

Panopæa arcuata Orb., *Pal franc.* pl. 355, figs. 3, 4. Neocomian=P. rostrata Math.

1866. Anatina n. sp. Stoliczka, North-Western Himalaya, *Mem. Geol. Surv., India*, Vol. V, p. 116.

Unfortunately only one well preserved specimens is available. It is a very elongated depressed left valve. The umbo is situated rather far forward and is rounded. The anterior region is relatively elongated and elegantly rounded, the posterior region greatly extended and gradually tapering. The surface is ornamented with irregular concentric furrows.

The French species is larger than the specimen above described; yet amongst the Indian material, there are fragments indicating considerable dimensions. The only distinction lies in the umbonal region, which in the European species is somewhat broader while the anterior region is rather shorter.

Gieumal. Stoliczka collection.

Cardium gieumalense and *Pseudomonotis superstes*, both of which are very abundant in the sandstone and quartzitic slate, also occur sparingly in the quartzite.

[1] Zittel, Gosaubivalven, *Denkschr. d. k. Akad. d. Wissensch. Wien*, vol. XXIV, p. vi, fig. 1.

[2] loc. cit., fig. 3.

[3] Geinitz, Elbtalgebirge, *Palæontographica*, Vol. XX, 1st part, pl. L, fig. 9, from the lower Quader (cenomanian).

Before concluding these descriptions, it is necessary to mention two more forms occurring in a different rock, a dark arenaceous limestone crowded with shells; it is very similar to the strata of Dogger age from Spiti and Hundes and the question arises as to whether some confusion may not have happened in the labels.

CORBIS? MONTANA n.f. pl. 18, fig. 9.

The hinge is unfortunately concealed so that the genus cannot be precisely determined.

The shell is symmetrical, with a strongly curved umbo, ornamented with coarse, broad, transverse ripples, some of which are repeatedly subdivided. It is distinguished from all analogous Jurassic or Cretaceous forms owing to the greatest breadth being situated close to the lower margin.

One specimen. Chikkim. Krafft-Hayden collection.

AVICULA SP.

The specimen which is unfortunately incomplete, indicates an oblique form with coarse, partly alternating radial ribs. It apparently belongs to the group of *A.* (*Oxytoma*) *inæquivalvis*, which extends with but slight changes throughout the Jurassic and Cretaceous.

Stoliczka collection. Locality unknown.

The following list includes all the species determined :—

1. From the calcareous sandstone.

   Cardium gieumalense n.f. (very common).
   Cardium cf. *gieumalense*.
   Cardium n.sp. ind.
   Ostrea sp.
   Gryphæa aff. *Gaylei* Guer.
   Pecten sp.
   Tellina sp.
   Opis sp. (rare).

2. From the argillaceous quartzitic slate :

   Pseudomonotis superstes n.f. (very common).
   Arca ? sp.
   Cucullæa ? sp.
   Unicardium cf. *tumidum* Briart-Corn.
   Tapes Rochebruni Zitt.

Tellina cf. *strigata* Gf.
Aporrhais aff. *Dupiniana* Orb.
Holcostephanus (*Astieria*) aff. *Atherstoni* Sharpe.
Hoplites (*Parahoplites*) sp.
Hoplites (*Stoliczkaia*) cf. *dispar* Orb.

3. From the grey quartzite.

Pseudomonotis superstes n.f. (rare).
Avicula ? aff. *Sanctæ Crucis* Pict.-Camp.
Lima aff. *Arzierensis* *Lor.*
Opis sp. (common).
Lima sp.
Cardium sp.
Cardium n.sp. ind.
Cardium gieumalense n.f. (rare).
Panopæa cf. *arcuata* Orb.

4. From the dark "lumachell" (? Dogger).

Corbis montana n.f.
Avicula sp.

Amongst Stoliczka's[1] types the following do not occur in the material examined.

MYTILUS MYTILOIDEA BLANF. (previously described by Blandford.[2] From the illustrations it is not possible to ascertain whether this may not represent some other genus for instance *Inoceramus*.

PECTEN BIFRONS SALTER figured in Salter's Palæontology of Niti[3] *Amusium demissum* Bean (an identification which, in any case, would need revising, especially as Stoliczka took the Gieumal sandstone for Jurassic.

ANATINA SPITIENSIS STOL.

Blanford has also figured a *Cyprina* ? *trigonalis*[4] which together with "*Avicula echinata*" our *Pseudomonotis superstes*, occurs abundantly in the Gieumal sandstone. Blanford's fig. 4 represents an undeterminable cast, and the same is the case with fig. 5, which, however, suggests the impression of a *Trigonia*. This form does not occur amongst our material.

[1] See *Mem., Geol. Surv., India*, Vol. V, 1866, p. 114.
[2] *Journ. Asiatic Soc. of Bengal*, 1863, pl. IV, fig. 8.
[3] Salter's Palæontology of Niti, pl. XXII, fig. 5 *non* figs. 6, 7 ; cf. Stoliczka, p. 74 ; the latter are jurassic.
[4] *Journ. Asiatic Soc. of Bengal*, 1863, p. 135, pl. IV, figs. 4, 5.

In attempting to estimate the stratigraphical value of this small fauna, we may first take into account the age of the underlying Spiti shales. In this respect the late Professor Uhlig had kindly communicated to me the following particulars.

"The fossils from the Spiti shales have not hitherto been collected strictly in accordance with their stratigraphical horizons. A subdivision of the Spiti shales into three zones was first established by L. C. Griesbach and C. Diener, who observed that the newest zone, the "Lochambel-Beds" gradually merges into the overlying Gieumal sandstone. These Lochambel beds cannot therefore strictly represent a single palæontological unit but must include a succession of palæontological horizons. The first result of a preliminary examination of this fauna, published in 1895,[1] was to the effect that it belongs to the Berrias stage, but also exhibits affinities to the upper tithonian on the one hand and on the other hand, to the valanginian. Further study has revealed the presence of a considerable number of forms which in Europe are essentially characteristic of the lower neocomian or valanginian, particularly amongst the *Hoplites*, for instance *Hoplites* (*Kilianella*) *pexiptychus* Uhl., *Hoplites* (*Neocomites*) *neocomiensis* d'Orb., *Hoplites* (*Thurmannia*) *Thurmanni*. They are accompanied by other forms of *Hoplites*, which must be regarded as new species, but which bear the closest relation to lower neocomian types. Some of the ammonites from the Lochambel beds, such as *Acanthodiscus subradiatus* or *Simbirskites* aff. *discofalcatus* Lah. are even related to middle neocomian or hauterivian forms.

In view of the remarkable development of valanginian *Hoplites* it seems improbable that we should be merely dealing with forerunners of the true valanginian fauna, such as might have developed in India earlier than in Europe, at a time corresponding therefore with the Berrias stage. From the evidence derived from our studies of the European faunæ it appears far more likely that the Lochambel beds also include the valanginian horizon. We cannot even exclude the possibility of the presence, within the Lochambel beds, of the lowest zones of the middle neocomian, though the probabilities are not in favour of this view. The presence of the higher horizons of the middle neocomian is not supported by any palæontological evidence.

[1]Geolog. Expedition in den Z. Himalaya, *Denkschr. d.k. Akad. d. Wissensch, Wien., math. nat. Classe*, LXII, 1895, p. 55.

Since the overlying Gieumal sandstone passes by interstratification into the Lochambel beds, the geological age of its lower limit is fairly accurately determinable. The base of the Gieumal sandstone cannot be older than upper valanginian nor newer than middle hauterivian."

The character of the fauna above described agrees perfectly with this conclusion. The bivalves are not of much value for chronological determinations. Amongst the ammonites, the *Astieria* is decidedly neocomian: related forms in Europe are of wide occurrence in the valanginian and hauterivian, while stray examples even reach the barremian. The valanginian is excluded as a result of Uhlig's researches. The fossil therefore indicates a middle or upper neocomian horizon. Our *Parahoplites* has its closest ally in Europe at the junction of the aptian and Gault, and indicates therefore a middle Cretaceous age; *Stoliczka dispar* in Europe, characterises the Gault and cenomanian, while in India it occurs in the "Ootatoor group" (cenomanian).

If therefore we apply the results of European investigations to Himalayan geology, we are led to look upon the Gieumal sandstone as an assemblage of beds ranging from middle neocomian up to the base, at least, of the upper Cretaceous. The overlying Chikkim series, whose conformity with the Gieumal sandstone has been positively asserted[1], must therefore include representatives of the upper Cretaceous.

From the point of view of geographical distribution, the occurrence of an *Astieria* of the group of *A. Atherstoni* is interesting; this is a characteristic form of the Uitenhage formation, while, according to information kindly communicated to me by Herr R. Folgner, it also occurs at the junction of the valanginian and hauterivian in the Salt Range (Chichali Pass). A related form also occurs in the Spiti shales. This may perhaps indicate free communication between the neocomian seas of the Himalayan region, and the oceans further to the south-west;[2] very closely related forms occur, indeed, in Europe[3].

It is strange, therefore, that the bivalve-fauna of the Himalaya should not contain any of the forms met with in the Uitenhage

[1] Griesbach, *Mem. Geol. Surv., India*, Vol. XXIII, p. 81.

[2] For a full discussion of this question, see Kitchin. Uitenhage formation, *Ann. S. Afr. Mus.* 1908, p. 51.

[3] See Kitchin *loc. cit.*

formation. The Gieumal sandstone contains no trace, apart from Blanford's doubtful *Trigonia*, of the *Trigoniæ* which occur so widely not only in South-Africa but also in German East-Africa, in the "Oomia group" of Kachh, as well as in Hazara (Afghanistan); in spite of the incompleteness of the Gieumal fauna collections, this absence can scarcely be accidental.

In general the preservation of the bivalves is too unsatisfactory to permit any weighty conclusions, in consequence of the resulting uncertainty of the identifications. The local character of a portion of the fauna also detracts from the value of the evidence. For instance *Cardium Gieumalense* and *Corbis ? montana* are striking examples of local types. Likewise *Pseudomonotis superstes* exhibits strong Jurassic affinities. The Himalayan Dogger has yielded two undescribed species of *Pseudomonotis* belonging to this same type. The Spiti shales, nevertheless, do not yield any connecting links, all the Pseudomonotidæ from that formation being smooth. The commencement of the deposition of clastic sediments at the upper limit of the spiti shales corresponds with a radical change in the fauna. The numerous ammonites dwindle away, there is a complete disappearance of *Astarte, Inoceramus, Ancella, Nucula*, of all those genera of bivalves, therefore, that communicate to the Spiti shales fauna its special character, while *Cardium, Ostrea* and *Pseudomonotis* take their place. Both the lithology and fauna of the Gieumal sandstone indicate a shallowing of the sea (according to Walter, all the species of *Cardium*, with few exceptions, live at feeble depths). This shallow-water fauna, unrelated to that of the Spiti shales, *must therefore have migrated from* some other region; this region also became the last refuge of *Pseudomonotis*, a genus which elsewhere appears to have been extinct in neocomian times. In this connection it is worth considering the close connection between this genus and the upper Cretaceous *Meleagrinella* (=*Eumicrotis*) from North America.

B. CHIKKIM LIMESTONE FROM SPITI.[1]

The material at my disposal includes a grey, arenaceous marl, weathering brown, crowded with the remains of foraminifera. The forms described below are of relatively large dimensions, and only need a feeble magnification for their study. They are not of any

[1] See Stoliczka, *Mem. Geol. Surv., India*, Vol. V. 1866, p. 116.

stratigraphical value, but may be of assistance locally in the case of any further geological examination of this series.

NODOSARIA sp. 1.

The chambers are large, rounded, smooth, separated by a deep slit with a rapid ratio of increase; five chambers are preserved, the initial and last one being absent; nevertheless the general appearance indicates that the total number was small and that the form should be compared with those of the group of *Nodosaria soluta* Reuss[1].

Chikkim. Krafft-Hayden collection.

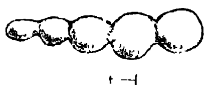


FIG. 4.

NODOSARIA sp. 2.

The chambers are elongate, oval, smooth, with oblique partitions; the first and last chamber are missing. These characters recall the group of *N. filiformis* Orb.[2]

Chikkim. Krafft-Hayden collection.

FIG. 5.

[1] Brady, Challenger Report, pl. 62, figs. 13-16.
[2] Brady, Challenger Report, pl. 63, figs. 3-6.

NODOSARIA sp. 3.

1866. *Nodosaria* sp. Stoliczka, North-Western Himalaya, *Mem. Geol. Surv., India*, V, p. 118.

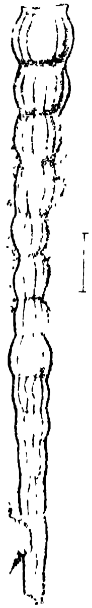


FIG. 6.

A very large *Nodosaria* with rounded-oval, occasionally somewhat elongate, longitudinally striated chambers, belongs to the group of *N. Zippei* Reuss.[1] as had already been correctly indicated by Stoliczka.

Chikkim. Stoliczka collection.

NODOSARIA 4.

1866. Dentalina cf. annulata Stoliczka, *Mem. Geol. Surv., India*, V, p. 118.

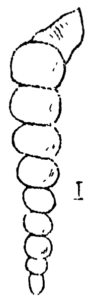


FIG. 7.

[1] Bohmische Kreide, pl. VIII, figs. 1-3.

A somewhat curved form (*Dentalina*), the convex side of which is shown in the illustration. It has rounded, somewhat compressed chambers. The last chambers are missing. The first chamber seems to be drawn out to a point. In the neighbourhood of the embryonic chamber the specimen is not well preserved and it is not quite certain whether, here, the chambers do not lose their rounded outline. This form recalls *Nod. annulata* Reuss as illustrated by Alth[1] from the upper Cretaceous, in which, however, the first chambers have distinctly flattened surfaces.

Chikkim. Stoliczka collection.

CRISTELLARIA sp. 1.

A large form with the earlier chambers spirally coiled, and followed by about three detailed chambers. the septa of which are perpendicular to the direction of elongation of the detached portion, the chambers of which no longer reach the coiled portion. The outer margin is keeled. The forms nearest related are *Cristellaria lituiformis* Reuss[2] and *Cristellaria lituola* Reuss.[3]

Chikkim. Krafft-Hayden collection.

FIG. 8.

CRISTELLARIA sp. 2.

1866. Haplophragmium sp. Stoliczka *Mem. Geol. Surv., India*, Vol. V, p. 118.

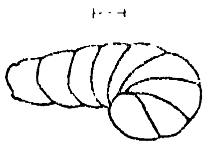


FIG. 9.

[1] Geogn.-palæontol. Beschreibung der Umgebung von Lemberg, *Haidingers naturwissenschaftliche abhandlungen*, *Wien*, III, pl. XIII, fig. 29.

[2] Zur Kenntnis der tertiaren Foraminiferenfauna, *Sitzungsberichte der Wiener Akad. d. Wissensch*, Vol. XLIII, 1st part, pl. IV, fig. 50.

[3] Bohmische Kreide, pl. XXIV, fig. 47, p. 109.

This form closely resembles the one previously described but has a larger number of detached chambers (five). Closely related is the tertiary *Cr. rhomboidea* Czjzek.[1]

Chikkim. Krafft-Hayden and Stoliczka collections.

CRISTELLARIA sp. 3.

1866. Rotalia sp. Stoliczka, North-Western Himalaya, *Mem. Geol. Surv., India*, Vol. V, p. 118.

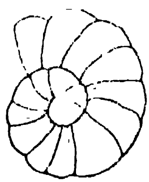


FIG. 10.

A spirally coiled form with strongly projecting, slightly curved broad septa and numerous chambers. *Cristellaria* (*Robulina*) *pterodiscoidea*[2] Gumbel resembles this form with respect to the structure of the septa, while *Cristellaria Kunkeri* Reuss[3] has the same outline with a similar rapid increase of the height of the whorls.

Chikkim. Stoliczka and Krafft-Hayden collections.

TEXTULARIA sp.

1866. Textularia 2 sp. Stoliczka, *Mem. Geol. Surv., India,* Vol. V, p. 118.

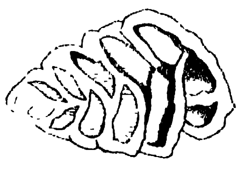


FIG. 11.

Sections of two *Textularia* one of which was compared by Stoliczka with *T. anceps* Reuss. One of these specimens is undeterminable,

[1] *Haidingers naturw. Abhandlungen, Wien*, Vol. II, pl. XII, figs. 21-23.
[2] Gumbel, *Abhandlungen d. bayr. Akad. d. Wiss.*, Vol. X, pl. 1, fig. 72.
[3] Foram. d. norddeutschen Hils und Gault, *Sitzungsberichte d. Wiener Akad. d. Wissensch.*, Vol. XLVI, 1st part, p. VIII, fig. 6.

while the other (text figure 11) by its laterally expanded chambers, recalls *T. Baudouiniana* Orb.[1]

Chikkim. Krafft-Hayden and Stoliczka collections.

These sections exhibit, besides remains of *Textularia*, *Dentalina* and other forms, a great abundance of *Globigerina* chambers.

One of the fragments referred by Stoliczka to the Rudistæ is amongst the material handed over to me; its fibrous structure plainly shows it to be a fragment of *Inoceramus*.

The only missing specimens out of the material described by Stoliczka[2] are a *Nodosaria* (said to resemble *N. intercostata* Reuss) and a *Cristellaria sp.*

Besides the above described forms, I have had access to Griesbach's collections from the so-called Chikkim limestone of Hundes[3]; the matrix is a light-grey to white limestone crowded with shell fragments. The rock rests upon the Gieumal sandstone and was therefore referred by Griesbach to Stoliczka's Chikkim series of Spiti, from which it entirely differs lithologically. It is, therefore, not quite certain whether it may not represent a Jurassic rock from the "exotic series". The presence of small canaliculate belemnites related to *B. Gerardi* lends support to this conclusion, though also occurring in the neocomian of the Salt-Range (see the special description). *Astarte hundesiana* has its nearest analogue in the group of *A. striato-costata* from the Jurassic of Europe, while *Cucullæa leionota* resembles *Cucullæa Uhligi* from the Himalayan Dogger. Further discoveries will perhaps settle the exact age of these rocks.

CUCULLÆA UHLIGI n. sp. pl. 19, figs. 8, 9*a*, *b*, 10*a*, *b*.

A large form with rounded, quadrate outline. The umbo is central, rounded, and strongly convex. Posteriorly to it is an area marked off from the remainder of the shell by an angulation whose sharpness decreases towards the posterior margin. The hinge line is slightly curved; the anterior and posterior margins converge towards it and are connected with it without any sudden angle. The ligament area is tall, ornamented with broad oblique ledges, separated by fine furrows. The shell is moderately convex. The hinge is not visible.

[1] Egger, Foraminiferen aus den oberen Kreidemergeln der oberbayrischen Alpen, *Abhandlungen bayr. Akademie d. Wissensch*, Vol. XXI, pl. II, fig. 10.
[2] See *Mem. Geol. Surv., India*, 1866, Vol. V, p. 117.
[3] Griesbach, *Mem. Geol. Surv., India*, 1891, Vol. XXIII, p. 80.

In addition to the lines of growth, the surface carries coarse, ill-defined, irregular concentric swellings, which increase in number and strength with increasing growth. Well-preserved specimens also show fine, alternating, radial striations, especially noticeable towards the margin.

This beautiful species does not seem to be closely related to any Cretaceous fossils. In India there are certain forms such as *Trigonarca Brahminica* Forbes[1] from the "Arrialoor group" and *Trigonarca gamana* Forb.[2] from the "Ootatoor group," which are not unlike in shape, but are nevertheless distinguished by the convergence of the upper and lower margins, which are parallel in the Tibetan form; the species first named also differs in the ornamentation of the ligament area.

Arca ligeriensis Orb[3] from the turonian differs by its elongate, rectilinear, lower margin, its greater convexity, and the absence of radial ornamentation; nevertheless it would seem to be one of the closest related forms (provided, of course, that the hinge of the present form should be similar and should correspond with that of *Arca.*) *Cucullæa brevis* Gerhardt [4] from the aptian, differs owing to the rectilinear course of the lower margin, the more oblique direction of the angulation, which limits the area and which remains distinct in the later stages of growth, and owing also to the absence of radial striations.

This form also seems to be present in the Gieumal sandstone.

Far closer related than any of the Cretaceous *Cucullæa* is a form from the Dogger of Spiti and Hundes, *Cucullæa leionota* Salter.[5] Its umbo is situated more anteriorly and is larger. The Spiti shales have not yielded any connecting links, it is advisable, therefore, to keep both forms separate.

Common. East of Laptel E. G. Hundes.

ASTARTE (VEL ERIPHYLA ?) HUNDESIANA n.sp., pl. 19, figs. 3 : 7.

Triangular, rounded, with pointed umbo, sub-centrally situated; anterior margin concave, posterior and lower margins well rounded,

[1] Stoliczka, Cretaceous fauna of Southern India, *Pal. Ind.*, Vol. III, pl. XVIII, fig. 13, pl. XX, figs. 1, 3.

[2] *Op. cit.*, pl. L, fig. 7.

[3] *Pal. Franc.*, pl. 319.

[4] Steinmanns Beitragen zur Geologie, Pal. Sudamerikas, *Neues Jahrbuch fur Mineralogie*, Vol. XI, pl. V, fig. 4.

[5] Pal. of Niti., pl. XXIII, fig. 4.

convexity moderate. Anteriorly to the umbo is an obliquely sloping sunken lunula.

The ornamentation is very characteristic; in the earlier stages of growth, besides the lines of growth, it consists of fairly well defined, coarse, concentric swellings, about twice the width of the intervening furrows. With increasing growth the concentric swellings become much broader and irregular, they become much less distinct, and finally less conspicuous than the lines of growth: perfectly identical changes are observed during the development of *Astarte obovata* Sow.[1]

The hinge in the right valve includes two cardinal teeth, of which the posterior one is large and thick. Unfortunately it is impossible to ascertain the presence or absence of lateral teeth, so that the generic reference, whether to *Astarte* or *Eriphyla*, must remain uncertain. The external ligament was supported by a fulcrum.

The shape is very variable. In addition to the type in which the height and breadth are about equal, there are individuals in which the breadth greatly exceeds the height. The inner margin is finely crenulated throughout.

The alteration in the character of the ornamentation during the growth of the individual distinguishes this form from all other Cretaceous species; this is the case, first of all with *Eriphyla Stuhlmanni* Muller from the neocomian of Ntandi,[2] which, in its earlier stages, thoroughly agrees in shape with the typical form of the Tibetan species. When full-grown, both forms are, however, totally different.

The broader variety of our species is very similar in shape to *Astarte Beaumonti* Leym.[3] from the spatangoid-limestone of the hauterivian in the Paris basin, in which, however, the ornamentation becomes completely obsolete, a character particularly emphasised by d'Orbigny in his descriptive text.

Other forms externally similar such as *Cytherea libanotica* Noetling[4] with absolutely identical ornamentation or else *Cyrena securis*

[1] Coquand Aptien de l' Espagne, pl. XIII, fig. 3.

[2] Versteinerungen der jura u. d. Kreide in Deutsch-Ostafrika, 7. Zur Oberflachengestaltung und Geologie von Deutsch-Ostafrika von. W. Bernhardt, Berlin 1900, pl. XX 1, figs. 3-4.

[3] d'Orbigny *Pal. Franc.* pl. 260, p. 60.

[4] Entwurf einer Gliederung der Kreideformation in Syrien und Palastina, *Zeitschrift d. Deutsch. Geol. Ges.* 1886, Vol. XXXVIII, pl. XXVI, figs. 2-4.

Meek[1] and *Circe discus* Math[2], both of which are identical in shape, differ in the constitution of the hinge.

The numerous forms of *Astarte* from the Spiti shales are all easily distinguished from the present form.

In the Jurassic of Europe, on the other hand, there occurs a very closely related type, this is *Astartestriato-costata* Gold.[3] from the Malm. In the characters of the ornamentation it agrees perfectly with the Indian form. It is also sometimes narrower (type), sometimes broader (var.); its umbo is, however, less pointed, and the concentric swellings of the early stages are not compressed but are completely rounded, moreover the Indian form is distinctly convex, especially in the umbonal region. The bathonian forms figured by Quenstedt[4] as *Astarte depressa* are even closer, especially with regard to the concentric ridges in the earlier stages of growth, but the posterior margin is more rounded than that of the Indian form, whose general shape is more distinctly triangular. This latter distinction also holds good for *A. striato-costata* in Lahusen[5] from the Oxfordian. *Astarte trembiazensis* Lor.[6] from the Oxfordian of Switzerland is smaller, less convex and is intermediate, with respect to proportionate height, between the two Indian varieties. The interior of the lower margin is similarly crenulated.[7]

Common. East of Laptel E. G. Hundes.

BELEMNITES sp. related to B. Gerardi, pl. 19, figs. 11, 12.

There are two specimens of a small belemnite with a narrow groove. In section it is round or slightly oval. The state of preservation is insufficient to say anything definite about furrows or concentric markings. There is no indication of lateral grooves. There is a great resemblance between this fossil and *Belemnites Gerardi* Oppel from the Spiti shales[8] in which the furrow is broader, though the section is analogous. The early stages of *B. alfuricus*

[1] Stanton, *Bull. U. St. Geol. Surv.*, pl. 106, fig. 23, figs. 1-3.

[2] Gosaubivalven, *Denkschr. k. Akad. Wien.*, Vol. XXIV, pl. III, fig. 7.

[3] Petr. Germ., pl. 134, fig. 18*a*, *b*.

[4] Jura, Vol. LXVII, figs. 29, 30.

[5] *Mem. com. geol. russ.* I, Die Fauna der jurass. Ablagerungen d. Rjasan Gouv. pl. II, fig. 26.

[6] *Schweizer palæont. Abhandlungen*, Vol. XXVIII, pl. IV, figs. 24-26.

[7] See also the quadrangular *Astarte Wiltoni* and the orbicular *A. angulata* in Morris and Lycett, Mon. of the Brit. Great Ool Moll. pl. IX, fig. 16 and pl. XXXV, fig. 20 from the bathonian.

[8] See Uhlig, Spiti shales, *Pal. Ind.* (15), Vol. IV, of 386.

Bohm.[1] are even closer. Dr. Folgner has kindly informed me that *B. Gerardi* also occurs in the neocomian of the Salt Range. On the other hand, the fossil in question does not resemble any upper Cretaceous forms.

Two specimens. East of Laptel E. G. Hundes.

EXPLANATION OF PLATES.

PLATE 18.

The fossils figured in this plate all belong to the Gieumal sandstone, with the exception, possibly, of figure 9.

FIG. 1*a*, *b*.—*Hoplites* (*Parahoplites*) sp. natural size, Lingti R., p. 205.
FIG. 2.—*Stoliczkaia* cf. *dispar* Orb., natural size. Lingti R., p. 206.
FIG. 3.—*Cardium* n. sp. ind. left valve, natural size. Gieumal, p. 199.
FIG. 4.—*Cardium* cf. *Gieumalense* n. f. right valve, natural size. Gieumal; p. 199.
FIG. 5*a*, *b*, *c*.—*Cardium Gieumalense*, n.f. right valve, natural size. Gieumal; p. 198.
FIG. 6.—*Pseudomonotis superstes* n.f. left valve. natural size. Gieumal. Ornamentation completed from another specimen, p. 201.
FIG. 7. *Pseudomonotis superstes*, n.f. right valve, natural size, Gieumal, p. 201.
FIG. 8.—*Avicula ?* aff. *Sanctæ-Crucis* Pictet-Camp. natural size. Gieumal. Umbonal region restored from another specimen, p. 207.
FIG. 9*a*, *b*.—*Corbis ? montana* n.f. natural size. Gieumal, p. 210.
FIG. 10.—*Panopæa* cf. *arcuata* Orb., natural size, Gieumal, p. 209.
FIG. 11*a*, *b*.—*Cardium* n.sp. Gieumal.
11*a* natural size, 11*b*, ornamentation, enlarged.
FIG. 12.—*Aporrhais* aff. *Dupiniana* Orb. (in Pict-Camp) cast. natural size. Chikkim, p. 204.
FIG. 13*a*, *b*.—*Lima* aff. *Arzierensis* Loriol, Gieumal.
13*a* lateral view, natural size; 13*b* ornamentation, enlarged, p. 207.
FIG. 14.—*Lima* aff. *Arzierensis* Loriol, cast. natural size. Gieumal, p. 207.
FIG. 15.—*Tapes Rochebruni* Zitt. natural size. Chikkim, p. 203.
FIG. 16.—*Unicardium* cf. *tumidum* Briart-Cornet (in Geinitz). natural size, Chikkim. p. 203.
FIG. 17*a*, *b*, *c*.—*Arca* sp.
17*a*, outline, natural size;
17*b*, the same enlarged;
17*c*, cast, natural size. p. 202.
FIG. 18.—*Tellina* cf. *strigata* Goldf. Right valve. natural size. Gieumal, p. 204.
FIG. 19.—*Tellina* sp. Right valve. natural size, Gieumal, p. 201.
FIG. 20*a*, *b*.—*Gryphæa* aff. *Baylei* Guér, natural size. Gieumal, p. 200.

[1] Niederlandisch Indien Pal. Suppl. IV, pl. VIII, figs. 8, 9.

FIG. 21.—*Gryphæa* aff. *Baylei* Guér. ; view of the umbo. natural size, Gieumal, p. 200.

FIG. 22.—*Pecten* sp. natural size. Gieumal, p. 200.

PLATE 19.

A. Fossils from the Gieumal sandstone.

FIG. 1*a*, *b*, *c*, *d*. *Opis*. Cast. natural size. Gieumal, p. 207.
1*a*, anterior view.
1*b*, posterior view.
1*c*, lateral view.
1*d*, vertical view from above.

FIG. 2. *Opis* sp. Cast. natural size. anterior view. Gieumal, p. 207.

B. Fossils from the so-called.
"Chikkim Limestone" of Hundes (Griesbach-collection) from east of Laptel E.G.

FIG. 3. *Astarte* (*Eriphyla* ?) *hundesiana* n.f. Broad variety. natural size. p. 220.

FIG. 4.—*Astarte* (*Eriphyla* ?) *hundesiana* n.f. Broad variety. natural size. p. 220.

FIG. 5. *Astarte* (*Eriphyla* ?) *hundesiana* n.f. Broad variety. natural size. p. 220.

FIG. 6*a*, *b*.—*Astarte* (*Eriphyla* ?) *hundesiana* n.f. Type. natural size. p. 220.

FIG. 7. *Astarte* (*Eriphyla* ?) *hundesiana* n.f. Type, natural size. p. 220.

FIG. 8.—*Cucullæa Uhligi* n.f. natural size. p. 219.

FIG. 9.—*Cucullæa Uhligi* n.f. Ornamentation enlarged. The dots indicate the region to which this portion of the shell belongs. p. 219.

FIG. 10*a*, *b*.—*Cucullæa Uhligi* n.f. natural size. p. 219.

FIGS. 11*a*, *b*. 12*a*, *b*. *Belemnites* sp. natural size. p. 222.

FURTHER DESCRIPTION OF INDARCTOS SALMONTANUS PILGRIM, THE NEW GENUS OF BEAR FROM THE MIDDLE SIWALIKS, WITH SOME REMARKS ON THE FOSSIL INDIAN URSIDAE. BY GUY E. PILGRIM, D. SC., F. G. S., *Officiating Superintendent, Geological Survey of India* (With Plate 20).

The Specimen.

THE specimen which forms the main subject of the present paper is a fragment of the left maxilla of a bear, containing the perfectly preserved with m[1], which has the surface of the crown entirely hammered off, and the alveolus of the posterior root of pm[4]. A part of the zygoma is included showing the maxillo-jugal suture. A narrow strip of the palatine is also visible showing a portion of the maxillo-palatine suture. A small piece of the matrix is attached to the specimen, consisting of the pepper and salt sandstone with grains of medium fineness, which is so frequently met with in Middle Siwalik horizons.

Horizon.

This specimen was obtained from near the village of Hasnot, the well-known locality north of the Salt Range and west of the Tilla ridge, shown in the map which accompanied the author's paper on the correlation of the Siwaliks with Mammal horizons of Europe,[1] which has yielded so many remains of fossil mammals. It was given to Sub-Assistant Vinayak Rao by a villager and its exact locality was not ascertained. The character of the matrix, however, renders it likely that it came out of the Dhok Pathan zone. The possibility cannot, however, be entirely excluded that it may have occurred in the Tatrot beds, although the coarse grit or brownish sandstone so typical of the latter horizon are alike wanting in the portions of matrix attached to the specimen.

Description of the Specimen.

This maxilla was briefly described in *Records, Geol. Surv. India*, Vol. XLIII (1913), p. 290, but without a figure. It was there stated that it was impossible to refer it to any previously known genus, and the name of *Indarctos salmontanus* was proposed for it. The following description is a far more detailed one and is accompanied by figures in Plate 20.

[1] *Records, Geol. Surv. Ind.*, XLIII, Pl. 27.

The structure of the hindermost tooth, which combines characters peculiar to the last upper molar of *Hyænarctos*, *Ursavus*, and *Helarctos* leaves no room for doubt as to its belonging to a member of the family of the Ursidæ. Four main cusps are indicated in m^2 of which the two outermost are stronger; the antero-internal cusp is long and ridge-like and shows clearly a division into two. The postero-internal cusp lies somewhat behind the level of the postero-external one; behind these two cusps the tooth is prolonged into a very strong talon containing a low cusp internally and a small one externally, hanging on at the base of the large postero-external cusp.

The strong external cingulum runs into this latter cusp. There is also a well marked internal cingulum on the anterior two-thirds of the tooth. The talon is not symmetrically developed but is chiefly internal. Thus it comes about that the small external cingular cusp referred to above is connected to the hindermost point of the tooth by a straight marginal edge oblique to the antero-posterior axis. The surface of the tooth seems to be quite smooth and free from wrinkling.

	Indarctos salmontanus.	Hyænarctos punjabiensis.	Arctotherium bonariense.	Ursavus brevirhinus	Helarctos malayanus.	Ursus namadicus.	Ursus arvernensis.	U. etruscus.	U. isabellinus.
Length of m^2 . .	35	29	50	13	20	28 app.	29	35	34
Breadth of m^2 . .	27	27	35	10·5	13·1	16	16	21	17
Length of m^1 . .	app. 28	28·5	30	12	18	20	20	22	20
Breadth of m^1 . .	app. 25·5	28	35	11	13	17	15	17	15
$\frac{\text{Length of } m^1}{\text{Breadth of } m^1}$ . .	1·09	1·01	·86	1·09	1·38	1·17	1·33	1·29	1·33
$\frac{\text{Length of } m^2}{\text{Breadth of } m^2}$ . .	1·29	1·07	1·43	1·23	1·52	1·75	1·81	1·67	2·00
$\frac{\text{Length of } m^2}{\text{Length of } m^1}$.	1·25	1·01	1·66	1·08	1·11	1·40	1·45	1·59	1·70
Length of pm^4 .	..	29	..	12	11·8	15·6	..	..	..
Breadth of pm^4 .	..	24·2	..	8	9·1	12	..	..	..
Height of jugal process of maxilla.	app. 45	app. 45	..	..	16·5	..	..	..	..

Measurements of Ursidae.

The measurements of this tooth in millimetres as well as the other dimensions of the specimen are stated in tabular form above together with those of *Ursavus brevirhinus*, *Hyænarctos punjabiensis*, *Arctotherium bonariense*, *Helarctos malayanus* and some other species of *Ursus*.

Comparisons with *Hyænarctos*.

It will be seen that in point of size this species can only be compared with *Hyænarctos* and *Arctotherium* amongst the Ursidæ. Since, however, *Hyænarctos* (taking as the types of this genus *Hyænarctos sivalensis* Falc and *H. insignis* Gerv.) is characterised by perfectly square upper molars, it seems quite impossible to refer the present species to that genus, as not only is m^1 longer than broad, but a very pronounced talon is present in m^2.

Comparisons with *Hyænarctos punjabiensis*.

It cannot, however, be denied that the species *Hyænarctos punjabiensis* possesses precisely those structural features which are so obvious in *Indarctos*, only in a very much less pronounced degree. It is true that m^1 in this species is almost square, but if we refer to Lydekker's figure* of m^2 we shall observe the same prolongation of the postero-internal angle, though it has hardly advanced far enough to be called a talon. If however we should discover a form intermediate between *Hyænarctos punjabiensis* and *Indarctos salmontanus* it would be indeed difficult to draw generic distinctions between the three. It is perhaps unfeasible at present to separate *Hyænarctos punjabiensis* generically from the other known species of *Hyænarctos*, but in any case the features, which distinguish my species from *Hyænarctos sivalensis*, apply, though in a less degree, in a comparison with *Hyænarctos punjabiensis*, and seem to justify the establishment of a new genus for the recent find.

Connection with *Hyænarctos arctoideus*, Dep.

In my preliminary notice† of *Indarctos*, I suggested the possible connection between the Hasnot species and the species from the pontian beds of Montredon briefly described by Depéret under the name of *Hyænarctos arctoideus*‡ but without either figures or dimensions.

[1] *Pal. Ind.*, ser. 10, II, text fig., p. 228.
[2] l. c., p. 290.
[3] *Comptes Rendus Acad. Sci., Paris*, CXXI (1895), p. 433.

Schlosser[1] has ventured on identifying Depéret's species with a species of *Ursavus* from the pontian of the Bohnerz of Melchingen to which he has given the name of *Ursavus depereti*. It is not possible to arrive at any conclusion with the meagre information at our disposal regarding the species *Hyænarctos arctoideus*.

Mandible of *Hyænarctos palæindicus*.

I might here withdraw the tentative suggestion made in my preliminary notice of *Indarctos*, that the mandibular fragments (Ind. Mus. D. 9 and D. 10) figured by Lydekker in *Pal. Ind.* ser. 10, vol. II, Pl. 31, figs. 2, 3, and provisionally referred by him to *Hyænarctos palæindicus*, might possibly have belonged to *Indarctos*. The size and prominence of the zygomatic arch points to a mandible much stouter than this. Moreover, the dog-like qualities to which Lydekker calls attention are not such as one would expect in an animal which distinctly approximates to the true bears.

Comparisons with *Arctotherium*.

Arctotherium certainly shows some features of similarity to *Indarctos*, but apart from the improbability that American Pleistocene species, which are mainly southern in their distribution, should be generically identical with an Indian one of pontian age, *Arctotherium*, as typified by the species *A. bonariense*. P. Gerv., seems to be quite distinct from our species even in the few characters that are available for comparison. In *Arctotherium* the transverse diameter of m^1, far from being less than the antero-posterior diameter, often actually exceeds it. On the other hand the talon of m^2 in this genus is longer and more complicated than in *Indarctos*.

Comparisons with *Ursavus*.

I shall next consider the relations of *Indarctos* to the upper Miocene genus *Ursavus*, and compare the two as carefully as my materials allow. *Ursavus* also possesses a talon to m^2, but it is not so long as in the Hasnot species. Moreover, it seems to have been much more symmetrical. The four main cusps form a square, the two posterior ones being directly opposite one another; further there seems to be no trace of a sub-division of the antero-internal cusp into two. *Ursavus* resembles our form in the presence of strong cingula both internally and externally.

We find that the disproportion between length and breadth in m^1 of *Ursavus brevirhinus* is less marked than in the Indian

[1] Schlosser M., Beitrage zur Kenntniss der Saugethierreste aus den Süddeutschen Bohnerzen, *Geol. u. Pal. Abhandl.*, IX (1902), 149.

fossil. Even supposing agreement between the two species in the structure of pm^4 and otherwise, the points I have mentioned seem sufficient to justify a generic separation.

Comparisons with modern bears.

Modern bears with the exception of the South American species, *Tremarctos ornatus* and the Malayan bear *Helarctos malayanus* possess a talon to m^2, which is so much longer and more complicated than the one in question as to entirely preclude any comparison. Of the two exceptions to this, I shall first consider *Helarctos malayanus*

Comparison with *Helarctos malayanus.*

This bear in respect of size of talon in m^2 and relative length of the upper molars is evidently removed as far from our species in the one direction as *Ursavus brevirhinus* is in the other. The antero-internal cusp is divided as in *Indarctos* but in addition, the external cusp, which in the Hasnot specimen is obviously cingular in origin, has assumed much greater dimensions and has been shifted internally so as to be in a line with the two external cusps anterior to it. The talon is more developed externally than in *Indarctos* and is higher, being further complicated by stronger and more numerous cusps. On neither side of the tooth is the cingulum so well-developed as in the fossil, although this appears to be a somewhat variable character.

It has already been remarked that a part of the maxillo-palatine suture is visible in my specimen. The course of this is essentially different not only from what we see in *Helarctos malayanus*, but also in all other modern bears. Running alongside the teeth it does not leave them until it is opposite the midpoint of m^1. On the analogy of the other bears we may infer that it then proceeds obliquely inward at least as far forward as pm^4. In *Helarctos malayanus*, this suture leaves the line of the teeth opposite the hinder half of m^3 and ends up no further forward than m^2. In *U. isabellinus* and its allies it runs as far forward as pm^4 but leaves the teeth opposite m^3.

A point which seems worthy of mention is that in the fossil the maxilla is very much deeper and more stoutly built than in the living form not only absolutely, but in a measure quite out of proportion to the amount by which the molars of the one species exceed those of the other in size. This stoutness extends very markedly to the jugal process and to the jugal bone. A striking feature of the latter

is the extent to which it projects outwards from the face before running backward to join the zygoma. It seems probable that the more massive structure of the maxilla must be correlated not only with larger molars than in the living bears but also with larger premolars. Another small point connected with the fragmentary alveolus of the hinder root of pm^4 leads us with even greater certainty to the same conclusion. In *Helarctos malayanus* as in all modern bears as well as in the pliocene and pleistocene types referable to *Ursus*, the inner cusp (protocone) is situated almost on a level with the hinder outer cusp (metacone), both protocone and metacone being supported on a single root, only slightly inferior in breadth to the entire breadth of the crown of the first molar tooth immediately behind it. In *Hyænarctos* and *Ursavus* on the contrary the protocone lies very much more forward, on a distinct root of its own and the hinder root of pm^4 is comparatively small—less than half the width of m^1. If the Hasnot species possessed a pm^4 of the type of *Helarctos* and *Ursus* the diameter of the hinder alveolus would most certainly have been greater than is actually the case. We may, therefore, infer with a tolerable degree of certainty that the protocone rested on a distinct root and lay more anteriorly than is the case in *Helarctos*. Whether it corresponded exactly in position and size to the protocone in pm^4 of *Hyænarctos* and *Ursavus*, it is, of course, impossible to say. But in any case we are provided with another very important difference in structure from *Helarctos malayanus*, and we need feel no hesitation in placing the Hasnot specimen into a different genus from *Helarctos*.

Comparison with *Tremarctos ornatus*.

Coming now to *Tremarctos ornatus*, it seems that the general appearance of m^2 recalls the Hasnot specimen strongly. Apparently, however, all the internal cusps including those of the talon here become fused into a more or less continuous ridge broken here and there by small divisions. In its hinder part this ridge bounds the talonal margin. In the Hasnot tooth the talon is depressed and shows no trace of any such ridge. In its proportionately longer upper molars, *Tremarctos ornatus* approximates less nearly to *Indarctos* than does *Helarctos malayanus*. In other respects the points to which I have called attention as separating the two latter apply equally well to distinguish the fossil form from the recent South American species. It would, therefore, be quite unreasonable to attempt to trace a connection with such a geographically distant animal.

Ancestry and later history of *Indarctos*.

Passing now to the question as to (1) how the *Indarctos* type may have originated, (2) what it may have given rise to in later times, we must first reject the idea suggested in my first notice of this genus that *Helarctos malayanus* may have been its degenerate descendant. Although the structure of m^3 in the modern species is somewhat similar, yet the greater complication of the cusps and still more the difference in pm^4 is entirely against this theory. It seems most likely that *Indarctos salmontanus* represents the climax in size attained by this particular line which soon after became extinct, as has so frequently been proved to occur in such gigantic types.

As to its origin, it is of course not beyond the bounds of possibility that it may have descended from the tortonian or sarmatian *Ursavus*, or a closely allied form, but the much greater degree of corrugation in the latter and the more symmetrical talon of m^2 militates against it. We see moreover in the pontian *Ursus Bockhi*, which according to Schlosser is the direct descendant of *Ursavus*, the development of the *Ursavus* features along the very lines which one would have expected them to follow.

Considering the structural peculiarities shared in common by *Indarctos salmontanus* and *Hyænarctos punjabiensis*, to which attention was drawn on page 227, the question of a possible genetic connection at once suggests itself. Apart from the fact that both these species are believed to occur at the same stratigraphical horizon, it is unlikely that the one form is the lineal descendant of the other, for *Hyænarctos punjabiensis* has a deeper maxilla, but it seems highly reasonable to suppose that both of them represent slightly different lines of development from a smaller and less specialized *Hyænarctoid* ancestor. Such a form or a near ally of it suggests itself in the sarmatian *Hyænarctos laurillardi*, Menegh. from Monte Bamboli, but even smaller species conforming to the required structure may one day be found in the Lower Siwaliks, which up till now has yielded no Ursid remains whatever.

Since to my knowledge no upper teeth have been discovered either in the case of *Hyænarctos laurillardi* or *Hyænarctos atticus*, Dames, it is possible that one or both of them may have possessed the embryonic talon shown in m^2 of *Hyænarctos punjabiensis*.

It is doubtful how far the presence of such a talon in the last upper molar may be correlated with the size of the 3rd lower molar. It may be noted however that m_3 in *Hyænarctos sivalensis* is said to

have been comparatively small, and in *H. palæindicus* was either *very small or absent. This tooth is unknown in H. insignis.* On the other hand it is comparatively large in *H. laurillardi*, and moderately so in *H. atticus*. In this connection I would suggest that it might be wiser to consider the reference of the mandible figured by Lydekker in *Pal. Ind.* ser. 10, vol. II, Pl. 31, fig. 1 to *Hyænarctos punjabiensis* as provisional. The mandible in question was not obtained in the same season as the type maxilla, and so far as can be seen now the two specimens do not agree exactly either in colour or amount of wear, and therefore are unlikely to have belonged to the same individual, which was Lydekker's opinion at that time. Failing exact knowledge as to the actual association of the two, it seems as likely that the mandible belonged to the species *Indarctos salmontanus*.

Hyænarctos sivalensis and insignis.

No trace of a talonal structure exists in m^2 of either of the species *H. sivalensis* or *H. insignis*. As we have very strong reason to believe that both of these species occur at a considerable higher stratigraphical horizon than *H. punjabiensis*, we may infer that they are descended from a species which, in this respect at all events, was more primitive than *H. punjabiensis*. *H. insignis* was a smaller form, but the degradation of pm^2 to a single-rooted tooth in distinction from the double root of the corresponding tooth in *H. punjabiensis* is what might be expected in a later Ursid species.

Hyænarctos palæindicus.

Yet another line existed in the Middle Siwalik of India as the species *Hyænarctos palæindicus*, the dog-like affinities of which have been clearly shown by Lydekker.[1] The shortness of m^1 and the rounding off of its internal angles together with the obliquity of the external cusps of m^2 indicate, according to Lydekker, a nearer relationship to *Hemicyon* than is found in any other *Hyænarctos* maxilla. The supposed mandible of this species exhibits in its shallowness and slenderness, and in the absence of m^3 even greater unlikeness to the bears. In many respects this mandible reminds one of *Simocyon*.

Melursus theobaldi.

Passing to the true bears, ancestral forms such as are found in Europe in *Ursavus* and *Ursus bockhi* are absent from the Miocene and Lower Pliocene of India. The earliest Indian bear is the species *Ursus theobaldi*

[1] *Pal. Ind.* ser. 10, II, p. 232.

Lyd. from Kangra, the horizon of which is probably the Boulder Conglomerate zone, equivalent to the Upper Pliocene of Europe.

Lydekker* has clearly shown that this is to be assigned to the genus *Melursus*, and regards it as the direct ancestor of the recent *Melursus ursinus*, from which it follows that the aborted dentition of the latter is a recently acquired characteristic and not a survival of ancestral characters.

Ursus namadicus.

The only other fossil bear is *Ursus namadicus* of the Pleistocene of the Narbada valley. This species seems to me to be much closer to *Ursus arvernensis* Croiz. et Job. of the Upper Pliocene and Pleistocene of Europe than to *Ursus* (*Helarctos*) *malayanus* differing from it so far as concerns the upper dentition (which is alone known in *U. namadicus*) only by the broader m^1 and the larger and more posteriorly situated protocone of pm^1.

It may be permissible to place both of these forms into the subgenus *Helarctos*, but I am unable to regard *Ursus namadicus* as the direct ancestor of *Ursus* (*Helarctos*) *malayanus* in view of its much more elongated m^2. Schlosser† comments on its likeness to *Ursavus brevirhinus*. These two species indeed correspond in the breadth and simple structure of m^1, but the great difference of their geological ages amply accounts for their unlikeness in other respects. But in any case it may well be that *Ursus namadicus* and *Ursus arvernensis* represent another line apart from *Ursus* (*Helarctos*) *malayanus*.

The mammalian fauna of the older pliocene of India is too insufficiently known to allow us to be sure that the failure to find *Ursus* at this horizon is a proof of its actual absence from the fauna. Hence, though tempting, it would be premature to draw any deductions as to the migration from Europe to India of bears like *U. ruscinensis* or *U. arvernensis*, through stress of climatic conditions in the glacial period.

EXPLANATION OF PLATE.

PLATE 20.

FIG. 1.—*Indarctos salmontanus*, Pilgrim, left maxilla, surface view.
FIG. 2.—m^1 in the above, external side view.
FIG. 3.—the same, internal side view.

[1] *Pal. Ind.* ser. 10, II, p. 211.
[2] Schlosser M. Ueber die Bären and Bärenähnlichen Formen des Europäischen Tertiärs *Palæontographica*, XLVI (1899), p. 100.

ON THE PROBABLE FUTURE BEHEADING OF THE SON AND RER RIVERS BY THE HASDO. BY L. LEIGH FERMOR, D. SC., A.R.S.M., F.G.S., *Superintendent, Geological Survey of India.* (With Plate 21.)

Perhaps the most remarkable feature in the physical geography of Korea State is the direction of its drainage system. From the accompanying map it will be seen that with small exceptions the whole of the portion of the State represented—namely, that south of lat. 23° 30′, corresponding roughly with the portions of Korea south of the Supra-Barakar plateau, and forming about three quarters of the total area of the State—is drained by the Hasdo and its tributaries, the Budra, the Anjan, and the Gej. The exceptions are the north-west corner, which is drained by the Kewai, a tributary of the Son, flowing through Rewah State to the west; and the north-east borders, which are drained by tributaries of the Rer in Sarguja State to the east. The Hasdo is, of course, a tributary of the Mahanadi, so that the main drainage of Korea finds its way to the sea at Cuttack. But Rewah State and Pendra zemindari on the west of Korea are drained almost entirely by the Son already mentioned, and Sarguja on the east by the Rer. Both these rivers flow northwards, the Rer joining the Son in the Mirzapur district, and the Son being one of the main tributaries of the Ganges. The northern portions of Korea are also drained by tributaries of the Son, the Supra-Barakar rocks of the Deogarh range forming the watershed.

Southern Korea thus forms a drainage wedge, of which the waters flow south to the Mahanadi, driven in between two drainage areas the waters of which flow north to the Ganges. A reference to the map of India shows that the water flowing north *viá* the Ganges route has more than twice as far to travel before reaching the sea as water pursuing the southern route *viá* the Mahanadi. One is, therefore, not surprised to find that the Hasdo in its Korean course has a much steeper gradient than the upper reaches of the Son and the Rer on either side.

At Sanhat (Lat. 23° 29′) the Hasdo flows at a level of about 2,400 feet, whilst where it leaves the State in the south (Lat. 22° 59′) it is at only about 1,200 feet[1]. The Rer on the east shows a fall of not more than about 200 feet (approx. from 1,800 to 1,600 feet) in traversing, in a northerly direction from Jajga on the south to Jhilmili in the north, the same number of minutes of latitude, whilst the Son, pursuing an average northerly to north-west course through the Pendra zamindari and the Sohagpur tahsil of the Rewah State, falls from about 1,900 feet east of Pendra (Lat. 22° 45′) to about 1,450 feet near Sohagpur (Lat. 23° 19′) to the west of the present sheet, in a course of about the same length. The gradients are thus roughly as follows:—

Hasdo .	1,200 feet in	76 (34) miles	or 16 feet to the mile[2].
Son . .	450 feet in	75 (50) miles	or 6 feet to the mile.
Rer . .	200 feet in	62 (33) miles	or 3 feet to the mile.

Taking not the distances along the bends, but measurements in a straight line, Korea may be likened to an inclined plane with a gradient of 35 feet to the mile to the south, placed between two inclined planes dipping respectively at 9 feet to the mile to the north-west, and 6 feet to the mile to the north, the base of the Korean inclined plane being roughly on the same latitude as the summits of the Rewah and Sarguja planes and *vice versa*. Consequently, the Hasdo, where it leaves Korea in the south, is flowing at a much lower level than the Son and the Rer on the same latitude. In latitude 23° 0′ the Hasdo is flowing at about 1,200 feet, whilst the Son at the same latitude is at about 1,700 feet, and the Rer at about 1,800 feet. At this latitude the Son is only 20 miles to the west of the Hasdo, and the Rer only 38 miles to the east. It is, therefore, obvious that any tributaries of the Hasdo at this latitude flowing from either the west or the east must have relatively high gradients—higher indeed than the Hasdo itself, and very much higher than the Son and the Rer each of which is pursuing a fairly level course, largely alluvial, on elevated country on either side of the Hasdo.

[1] Very few heights are attached to the rivers on either the Atlas Sheet or the 1-inch maps of this country so that I am compelled to deduce approximate heights for given points from (1) such heights as are given in the neighbourhood, (2) the contouring of the maps and (3) such local knowledge of the country as I obtained during my visit.

[2] Distances measured along the bends. The numbers in brackets are the distances measured in a straight line

Sooner or later, therefore, such tributaries should have a chance of beheading the upper reaches of the Son to the west and of the Rer to the east and of diverting their drainage into the Hasdo. A reference to the map reveals at once two excellent cases where tributaries of the Hasdo have cut back the watershed very close indeed to the Son on one side and to the Rer on the other.

The beheading of the Son.

On the west side, the Budra river—which joins the Hasdo at an elevation of a little over 1,200 feet some 2 miles below Dewadand near the southern border of Korea—rises to the west and south-west in a multitude of tributaries, a large number of which head within 1 to 4 miles of the Son. The watershed between the Son and these nalas is very low and is frequently, judging from the 1″ map and my observations where I crossed it at two points, of an alluvial character, and is, therefore, in many places probably not more than 50 feet, and probably sometimes less, above the bed of the Son. It seems, therefore, certain that sooner or later the Son will be tapped at one of these numerous points of attack.

This may happen in two ways. *Either* a tributary of the Budra may erode back its head until it reaches the flood level of the Son in the rains, when the Son will discover this channel and commence deepening it with a rush of water. If the barrier were alluvial this cutting might be completed in one rains with the consequent diversion of the head waters of the Son into the Budra. But if the barrier were rocky it would probably take many years to deepen the channel to the level of the bed of the Son; and in such a case water from the Son would pass into the Budra only during the rains year by year, until a permanent diversion was effected. *Or secondly*, the Son might in a season of exceptionally heavy rains reach an abnormal level and overflow its banks, thus entering one or more of the attacking tributaries years earlier than would otherwise have happened.

Once the diversion had been effected, the gradient of the captured portion of the Son would speedily increase, and a gradually increasing length of the Son below the point of truncation would have its flow reversed.

The distance to which this reversal would, in the course of time, extend would naturally depend on the character of the watershed between the two drainage systems at the point where

it was breached, particularly the depth of sound rock below the surface, and its power of resisting erosion. But it seems likely that in any case the reversal would eventually extend as far as the junction of the Kewai with the Son (about 1,600 feet), thus also diverting into the Hasdo the drainage of the Kewai, which taps the north-west corner of Korea.

If we examine the 1″ sheets for the most likely spots at which such beheading might occur, three points seem to be specially favourable. One of these is a point about a mile south-west of Nakha (Lat. 22° 55′), where a tributary of the Sukhar, itself a tributary of the Budra, terminates only half a mile east of the Son, from which a minute tributary rises up to join hands. The watershed at this point may be a trifle high, as is suggested both by the contouring and by the existence of granitic outcrops just to the south of the nala: it cannot, however, be higher than 100 feet above the Son, and is probably much less. In addition the attacking tributary falls eastwards, in the course of a mile, to a much lower level than the Son, so that the watershed is bound to be breached sooner or later.

An almost equally likely spot lies on this same watershed some 3 miles further north near the village of Karangi (23° 57′). Half a mile east of this village the Dumar rises less than a mile from the Son, the height of the watershed above the Son being probably not more than about 50 feet. The Dumar has a considerably steeper gradient than the tributary of the Sukhar that is pushing the attack near Nakha. Thus, where it joins the Budra the elevation is about 1,400 feet, whilst on the watershed its elevation must be a little less than 1,800 feet. There is thus a fall of nearly 400 feet in the course of 6 miles, whilst the gradient in the Sukhar must be about 450 feet in about twice that distance. Without a more intimate knowledge of the ground it is impossible to predict which of these two tributaries will effect the beheading.

If the two tributaries noticed above are slower in their action than might be anticipated, then the capture may be effected still further to the south near the villages of Sakhua and Sakola (Lat. 22° 50′), where several of the head tributaries of the Sukhar approach within $1\frac{1}{2}$ to $1\frac{3}{4}$ miles of the Son, at a point where the map suggests that the watershed lies on alluvial ground. Although these tributaries have a low gradient at this point, so

that they will tend to cut back their heads more slowly, other things being equal, yet the height of the watershed above the Son must be very small, giving the latter river so much the greater chance of overflowing its watershed at a time of exceptional floods and so beheading itself.

Still further south the beheading might be effected by tributaries of the Bamni, the largest tributary of the Budra. But it seems to me that the beheading of the Son is more likely to occur at one of the first named points lower in the course of the Son, because the attacking tributaries near Karangi and Nakha have a steeper gradient, whilst the Son itself is larger and perhaps has a greater chance of entering the invading nalas at times of exceptional floods.

The beheading of the Rer.

Turning now to the eastern side of the Hasdo, it is seen at once that the Jhink Nala, a tributary of the Gej, which itself falls into the Hasdo some miles below where the latter leaves Korea, has already cut back its course so far that at Bhaduai (Lat. 23° 1′ Long. 83° 0′), two of its headwaters have reached a distance of only a mile from the Rer. The contouring of the 1′ map at this point suggests that the watershed between the Jhink and the Rer is fairly high above the Rer, perhaps 100 to 150 feet. But it seems certain that sooner or later the Jhink will behead the Rer at one of these two points. The probability of this is seen in the fact that the Jhink falls some 450 feet between its source and its junction with the Gej (about 1,400 feet) some 23 miles to the west. Between the probable point of beheading and Jhilmili — some 52 miles—the Rer falls from about 1,750 or 1,800 feet to a little over 1,600 feet (Jhilmili is 1,634 feet), probably 150 to 175 feet in all; comparing this elevation with that of the junction of the Gej and the Hasdo, it does not seem likely that a very great length of the Rer below the point of truncation will have its course reversed and turned into the Jhink. This probability is strengthened by the fact that below Jhilmili the Rer passes through rocky country with a much increased gradient, falling in the course of 50 miles from about 1,600 feet at Jhilmili to 1,074 feet at the Rehund H.S. (Lat. 23° 53′). So that eventually, indeed, the Rer is likely to recapture its lost headwaters when the barriers that must exist in this lower part of its course are eroded away.

Before this stage is reached, however, we may picture a period of great increase in the catchment area of the Hasdo, when the upper reaches of the Son (and of its tributary the Kewai) in Pendra and Rewah, both discharge their waters down one of the tributaries of the Budra into the Hasdo, and when the upper reaches of the Rer in Sarguja, perhaps as far down stream as Paharbula (Lat. 23° 11′) but probably no further, discharge their waters *viâ* the Jhink and the Gej also into the Hasdo.

Date of beheading.

To assign a date to this truncation is, of course, impossible in our present ignorance, not only of the exact data relating to this particular case, but also of rates of erosion and weathering in general. But, considering the proximity of the headwaters of the Budra to the Son and the insignificance of the intervening watershed, surprise should not be felt if the capture of the headwaters of the Son take place within the present century. The reader will perhaps best understand the probability of this ultimate beheading in the case of the Son by a glance at the map, the shading of which shows admirably the manner in which the multitude of relatively steeply graded tributaries of the Budra are cutting into the edge of the plateau on which the Son in false security pursues its meandering course.

Geological reasons for direction of drainage of the Hasdo.

It is difficult to advance definite reasons based on geological structure to explain this occupancy by the Hasdo of the larger portion of Korea State. The primary consideration is, of course, gradient to the sea, and it is likely that the country now drained by the upper reaches of the Son would also have been drained long ago by a southward-flowing river, were it not for the fact that the Pendra plateau, acting as the watershed between the drainage of the Bilaspur district to the south and of Rewah to the north, is composed of Archæan granites and gneisses, which have probably acted as a buttress against rapid erosion from the south, permitting the Gondwanas lying to the north of this buttress to be eroded and drained by a northward-flowing river of low gradient. This buttress is, of course, the extension of the protaxis of the Satpuras, which, as the author has discussed elsewhere[1], probably continues eastwards as far as the Ranchi plateau.

[1] Fermor, Geology and Coal Resources of Korea State, *Mem., Geol. Surv., Ind.*, vol. XLI, pt. 2, p. 164.

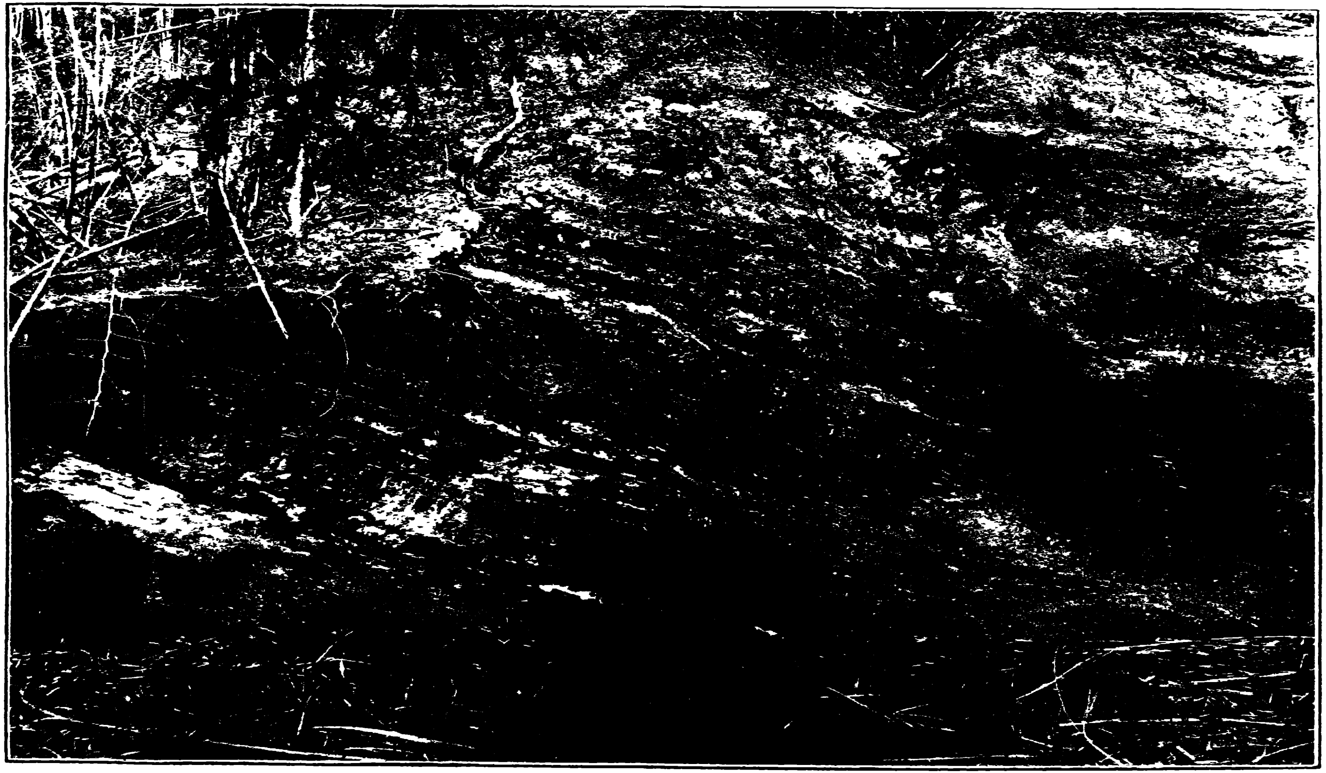
But if one considers the long strip of Gondwana sediments stretching from Rewah through Korea and Sarguja nearly continuously in a south-east direction as far as the Talchir coalfield, one cannot help thinking, in spite of the fact that portions of the boundaries of this strip are faulted, that the sediments were deposited by a great river flowing south east to the sea through a breach in the Satpuran protaxis in Korea and western Sarguja. The Vindhyan pebbles in the glacial boulder beds of the Talchirs in Korea were probably derived from Baghelkhand in the north-west and support this hypothesis. If this view be correct then the Hasdo is merely opening up once more this ancient pre-Gondwana channel across the Satpuran protaxis Where I have indicated the probability of one of its tributaries tapping the Son, the latter is flowing on top of the ancient Archæan Satpuran ridge, and consequently, owing to the relatively slow rate of erosion of the Archæans, the time of truncation of the Son may be more remote than I imagine, and beheading in this neighbourhood may be anticipated by one of the more northern tributaries of the Hasdo, such as, the Kulharia, working on the softer materials of the Gondwanas and thus tapping the Kewai directly.

In western Sarguja to the east of Korea the geological relationships seem to be less simple, and it is still more difficult to explain satisfactorily the northward drainage. But it is probably influenced by the fact that the continuation of the Satpuran protaxis to the east of the Korean breach begins to rise again in western Sarguja.

EXPLANATION OF PLATE.

PLATE 21.

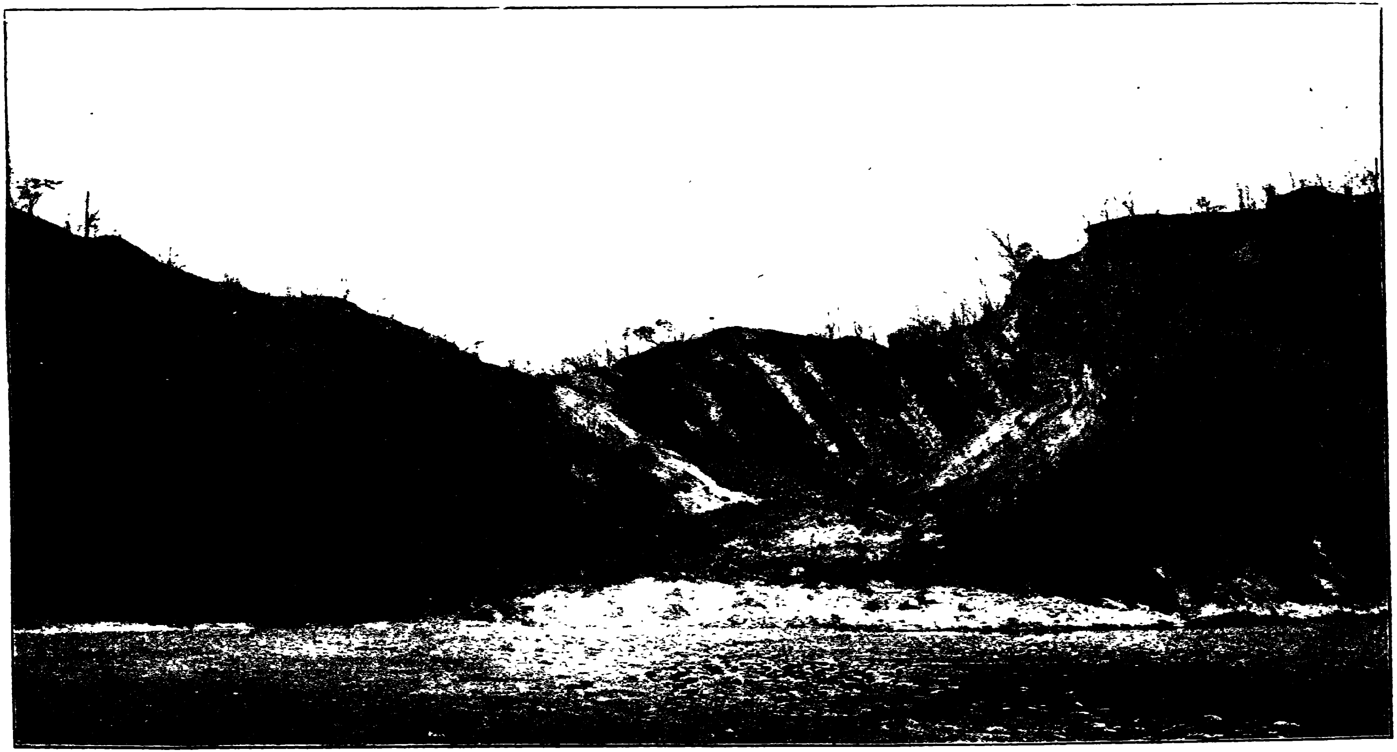
Geological Map of Korea State. Scale 1″= 4 miles.



Photograph by G. de P. Cotter

G. S. I. Calcutta.

COAL in PAKOKKU:



Photographs by G. de P. Cotter — G. S. I. Calcutta

COAL in PAKOKKU.

The steeply dipping seams on the western flank of the Pondaung fold opposite Tazu Village.

Photograph by G. de P. Cotter. *G. S. I. Calcutta.*

COAL in PAKOKKU:
Excavation of the three main seams in the Thongwa Chaung.